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ASSESSMENT OF THE EFFECTS OF POLLUTION ON FISHERIES AND AQUACULTURE IN JAPAN

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS

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UNITED NATIONS ENVIRONMENT PROGRAMME

AN ASSESSMENT OF THE EFFECTS OF POLLUTION ON FISHERIES AND AQUACULTURE IN JAPAN

by

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Tokyo, Japan

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
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Abstract

This paper attempts to make a quantitative assessment of the impact of pollution on the fisheries around Japan. Shortage of data caused the study to be confined mainly to Tokyo Bay and the Seto Inland Sea, though these areas included a large proportion of the reported cases of pollution. The main cause of pollution in general, and of damage to fisheries was oil pollution, followed by red tide. The impact on fisheries was assessed from reports of direct damage, and also by examination of trends in catches. No significant decrease in total catch was observed, but within the total there were differences between species, certain species (e.g. oceanic types) tending to decrease and others increasing. The need for careful monitoring and control of pollution is stressed.

PREFACE

During the course of this study, some obstacles were encountered in the analysis of factors which affect fishery resources. The initial problems were largely those of logistics, planning and decision-making. The mode and logistics of data compilation were decided upon but the problem of data arrangement, interpretation, and assessment remained. Our work on these and related problems led to the discussion presented in the following pages.

The most difficult problem has been that of clearly identifying and measuring the impact of environmental pollution on fishery resources in general. This is due to the fact that various factors are responsible for yearly changes in fisheries production. These include impoverishment of fishing grounds due to overfishing, changes in the physical and chemical condition of the marine environment, advancements in the field of fishing techniques and gears, and consumer demand. The impact of these variables taken alone and their interplay on fisheries production still require considerable clarification and it is essential that this is taken into account when assessing the effects of environmental pollution on marine resources. Moreover, in the process of compiling nation-wide data, it became clear that an over-all assessment of trends is virtually impossible. We have therefore limited the bulk of this report to a presentation of case studies undertaken in the region of Tokyo Bay and the Seto Inland Sea. We would like to point out that data presented in this report has been collected from various isntitutions, laboratories, and fishery experimental stations. Consequently there is an admitted lack of homogeneity in terms of scope and precision, and intercalibration has been difficult or impossible. Needless to say, this has created difficulty in the assessment of actual relationships.

It is encouraging that environmental pollution in Japan has been gradually decreasing since 1972 due to the enactment of the Environmental Protection Law. We hope this trend will continue, but it will only be possible through the continuation of concerted countermeasure programmes and environmental monitoring.

As mentioned above, the regions of Tokyo Bay and the Seto Inland Sea were selected as the focal points of the discussions presented in this report. Factors which were relevant in this selection included the serious state of pollution in these areas, together with the fact that fishery statistics and results of environmental surveys are well documented for these two specific areas. We very much hope that a data base system will be set up for these specific areas to provide the foundation for accurate prediction and assessment of the effects of environmental pollution on fisheries production in the future.

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1. AN OUTLINE OF WATER POLLUTION IN JAPAN

In recent years the Japanese economy has made rapid strides and progress as a result of the development and growth of numerous industries. One which has had considerable impact on the economic development of this country has been the heavy chemical industry. Unfortunately, however, the recent years have also witnessed an increase in discharged volumes of industrial and municipal wastes to such an extent that environmental pollution has come to be a problem of extremely serious proportions. This problem is illustrated in Table 1 and Figures 1 and 2 where annual changes in marine pollution which have been registered during the past six years in the coastal waters surrounding Japan are shown. The results clearly indicate that the highest numbers of registered cases of marine pollution have occurred in the vicinities of Tokyo Bay, Ise Bay, Osaka Bay and the Seto Inland Sea. In these four regions 1 486 cases were reported representing 63 percent of all reported cases on a nation-wide basis. Table 1 also demonstrates that pollution is on the rise in the coastal areas of Hokkaido and the Japan Sea. Classification according to source and type of marine pollution revealed that the majority of cases (84 percent) was due to oil and the next most important factor was the red tide (Figure 3). Industrial wastes totalled 64 950 000 tons of which 5 250 000 tons were acid and alkaline wastes, while 5 370 000 tons were due to dredging operations. Classification of the most frequent types of discharged industrial wastes dumped by vessels in 1974 are presented in Figure 4.

Geographic locations of fixed monitoring stations as well as pollutant dumping areas are shown in Figure 5; these stations and dumping areas were designated by the Maritime Safety Agency following a marine pollution survey which was conducted in and around the coastal waters of Japan. Water samples are collected twice yearly in summer and winter at the primary stations, and sea areas are divided into areas "A" and "B" in accordance with the Marine Pollution Prevention Law. Areas given the designation "A" are for the disposal of toxic chemicals such as mercury and cadmium, while those designated "B" serve as dumping sites for slag and metallic wastes. Samples of sea water and bottom sediments are collected annually in these areas for the analysis of COD, PCBs and heavy metals as part of a concerted monitoring programme.

A survey conducted in 1973 regarding the dispersion and landing of "waste oil balls" revealed that the regions of dispersion were more limited spatially than in a previous survey conducted in 1971; however, the problem still persists to a relatively wide extent. The results of the survey taken in 1973 also demonstrated that the concentration of petroleum hydrocarbons in the coastal waters of Japan was 0.02 ppm.

Diverse aspects of environmental pollution were evaluated in various surveys conducted in 1973. In the phase concerned with mercury contamination of some marine products, a total of 23 019 samples, including 22 403 of 303 marine species of fish and shellfish and 616 of plankters, were collected from 268 regions. Results demonstrated that 5 of 23 fish species from Minamata Bay, 5 of 28 species from Tokuyama Bay, 4 of 14 from the waterfront at Naoezu, and 5 of 19 from Kagoshima Bay exceeded the provisional control limit of 0.4 ppm total mercury. Furthermore, the mercury content of some freshwater species of fish taken from 9 rivers also exceeded the control limit. These results prompted the establishment of counter-measures aimed at controlling the mercury source, and operations for the removal of mercury-contaminated bottom sediments were concurrently implemented.

During the water quality phase of the survey 3 768 water samples taken from 634 water regions were examined. Of the total, 2 percent (76 samples) exceeded the environmental quality standard for total mercury; the results are summarized in Table 2.

In the phase of the survey concerned with bottom deposits, 5 186 samples were collected from 635 stations, of which 2.3 percent (120 samples from 25 stations) were found to exceed the provisional mercury standard (25 $\mu g/g$) for bottom deposits. In Table 3 areas are listed where eradication measures were instigated in order to promptly decontaminate the bottom deposits. Clean-up procedures have been implemented in most of the problematic areas. On 30 September 1974 environmental quality standards for water were established at "less than 0.0005 ppm" for total mercury, and "not detectable" for alkyl mercury.

A nation-wide survey of PCBs and agricultural chemicals was conducted in the regions of the sea surrounding Japan in 1972 and 1973. As shown in Table 4, 3 369 samples representing fish and shellfish were collected from 20 stations. Based on the results, guidelines were drawn up in order to ensure self-restraint in the operation of the fisheries industry.

The water quality phase of the survey examined 1 281 samples originating from a total of 282 aquatic regions, including those from 208 rivers, 28 harbours and 46 marine areas where sediments were found to contain PCBs at concentrations exceeding 1 ppm. The results are summarized in Table 5.

In the phase of the survey dealing with bottom deposits, a total of 1 789 samples were collected from 354 aquatic regions, which included 258 rivers, 38 ports and harbours and 58 marine areas. The results are presented in Table 6 and demonstrate that the sediments of 51 bodies of water exceeded the provisional control level for PCBs (10 ppm on a dry weight basis). Moreover, the number of aquatic regions in which the maximum concentration of PCBs either exceeded 100 ppm, ranged from 50 to 100 ppm, ranged from 25 to 50 ppm, or was less than 25 ppm, were 6, 8, 11 and 26, respectively. Removal of contaminated sediments in those areas which exceeded the provisional standards was considered to be urgently necessary; in some regions, such measures have already been finalized. The organochlorinated compounds, represented by DDT, BHC and dieldrin, illustrate this need for removal. Due to the fact that these compounds tend to remain in foodstuffs and in the environment as residues, extremely stringent restrictions and limitations on their use were enacted and enforced in 1971. Up until that year cases had been reported of marketed farm crops which contained dieldrin, DDT, etc. in quantities exceeding the residue standards for agricultural chemicals. Very few cases have been reported in recent years. Nevertheless, proof that significant residual quantities of these chemicals continue to persist in the environment has been demonstrated by the high concentrations of BHC, DDT and dieldrin detected in the bodies of birds inhabiting the region of the Seto Inland Sea during the period 1972 to 1973. This has been particularly striking among carnivorous species which inhabit beaches.

The current situation regarding regulation of the utilization of agricultural chemicals is presented in Table 7. Safety standards have been enforced to protect marine animals from pollution due to 54 different chemicals including CVP and PCB.

Finally, a recent characteristic of water pollution is its spread into coastal waters due to an increase in the influx of waste water discharge originating both from industrial and domestic sources in newly-developing urban areas. In those bodies of water which are partially enclosed, eutrophication problems arise as the result of the influx of nitrogen- and phosphorus-containing materials in addition to the problems created by organic matter. Values reflecting chemical oxygen demand (COD) for some important lakes and bays in Japan are presented in Figure 6 as some indication of the state of water pollution in this country.

2. THE PRESENT STATE OF DAMAGE TO FISHERIES DUE TO POLLUTION OF COASTAL WATERS

In this brief section discussion is confined to a description of damage to fisheries caused by oil pollution and outbreaks of red tide in recent years; a more detailed account has been precluded since damage to fisheries by these two causative agents has been accurately assessed only in the past few years.

2.1 Damage to fisheries due to red tides

Outbreaks of red tide were once generally characterized by their occurrence on a relatively small scale during the summer season in partially enclosed or sheltered bodies of water such as the Seto Inland Sea, Ise Bay, Mikawa Bay and Tokyo Bay. In more recent times, however, the incidence of seasonal red tide outbreaks has increased considerably as a result of progressive eutrophication of some marine environments, due to an increase in the discharge of municipal and industrial waste materials. Twenty-seven cases of red

tide-related damage were reported in 1973, costing a total of 591 million yen (approx. US$1.97 million). Although this figure is staggering, it does represent a decrease in comparison to 1972, when 33 cases costing 7 386 million yen (approx. US$24.6 million) were reported.

2.2 Damage to fisheries due to petroleum products and raw materials

A total of 58 cases of damage due to oil pollution of fishing grounds were reported in 1973, of which 41 resulted in damage totalling 1 768 million yen (approx. US$5.89 million). This figure, however, represents a decrease compared with those reported in 1971 and 1972. In 1973 pollution damage in marine regions caused by oil was 43 percent of the total number of pollution cases, and represented 47 percent of the total cost of the damages. In order to protect fishing grounds from oil pollution, the discharge of waste oil and oily ballast from ships has been strictly regulated by the Port Regulation Law and the Marine Pollution Prevention Law. However, damage to fisheries caused by oil spills resulting from grounding or collision of tankers is still on the increase and has become more of a serious problem in view of the increased flow of traffic (including "super-tankers") in ports and coastal waters.

3. THE PRESENT STATE OF MARINE RESOURCES IN COASTAL WATERS

Examination of some current trends in major fish resources has revealed an increase in the population of young mackerel (Scomber japonicus), a recovery in the population of sardine ("maiwashi", Sardinops melanosticta), while resources of anchovy ("katakuchi iwashi", Engraulis japonica) and round herring ("urume iwashi", Etrumeus micropus) have been relatively constant in recent years. In the case of saury ("sanma", Cololabis saira), the yield was less than the normal annual catch in 1974, but this may have been due to sea conditions during that year.

The catch yield of mackerel has been rapidly increasing from 1965, accounting for over a million tons in 1968 and 1969 and reaching a peak of 1.3 million tons in 1970; the annual catch decreased slightly in 1972 and 1973. As for sardines, the total yield has been increasing rapidly in the last few years from 0.02 million tons in 1970 to 0.35 million tons in 1974. The total yield of horse mackerel (Trachurus japonicus) has been gradually on the decline, decreasing from about half a million tons in 1965 and 1966 to 0.15 and 0.13 million tons in 1972 and 1973. The yield of common squid ("surumeika", Todarodes pacificus) has fluctuated annually, giving a maximum of 0.668 million tons in 1968, and a minimum of 0.346 million tons in 1973. In the case of saury, production remained at a rather constant level from 1964 to 1967, ranging between 0.21 and 0.24 million tons, but declined to a minimum of 0.06 million tons in 1969. During the subsequent years, the yield slowly recovered attaining levels between 0.18 and 0.19 million tons and even reached a maximum of 0.41 million tons in 1973. However, this was followed by a significant decline and a value of 0.135 million tons was reported as of November 1974. Data reflecting annual yield according to classification of each major fishery are presented in Table 8.

In view of the varying trends described in the last paragraph, it is difficult to discern or assess any general effect of environmental pollution to fishery resources on the basis of nation-wide statistics. It is therefore apparent that in order to evaluate, assess or predict the potential effect of pollution damage to fisheries, it is necessary to collect data and information for certain designated bodies of water. It is clear that only through a carefully planned and concerted programme can we hope to realize our aim, i.e. a meaningful assessment of the relationship between environmental pollution and damage to local fisheries. The following pages of this report therefore focus on a discussion of the problem under consideration for two geographical regions - Tokyo Bay and the Seto Inland Sea.

4. A CASE STUDY ON THE EFFECTS OF WATER POLLUTION ON FISHERIES

4.1 The present state of pollution and fisheries in Tokyo Bay

4.1.1 Natural conditions

4.1.1.1 Geographical features (see Figure 7)

The region of Tokyo Bay, inside an imaginary line drawn between Point Honmoku and Cape Futtsu, is characterized by a piled configuration, water depth under 30 m, simple sea-bottom layout, and smooth coastal lines. Reclamation operations have been carried out in some areas of the bay where the water depth is less than 5 m. Since 1912, when the first project was conducted along the waterfront of Kawasaki, approximately 290 km^2 have been reclaimed. This area represents more than 20 percent of the total area of Tokyo Bay (Figure 8).

To the south of Nakanose, the water is deep and provides an entrance to the bay. This entrance is characterized by a crooked channel 6 km wide and 50 m deep; off the coast of Kurihama, the depth increases to about 200 m.

When Tokyo Bay is represented by the area north of an imaginary line extended between Point Kannon and Cape Futtsu, the following specifications characterize the bay. It has a surface area of about 1 000 km^2, an average water depth of about 18 m and a capacity of about 17 900 million m^3. In addition 7 000 km^2 of river basin area belong to Tokyo Bay, and about 10 000 million m^3 of fresh water run into the bay each year.

4.1.1.2 Meteorological characteristics

The climate around the bay area is mild throughout the year, as indicated by the mean temperatures and humidities for the four seasons: spring (April) 13.5°C and 66 percent, summer (July) 25.2°C and 79 percent, autumn (October) 16.9°C and 77 percent and winter (January) 4.1°C and 57 percent. Extremes in air temperature are represented by those for the Yokohama area which records a minimum of about 6°C in February and a maximum of about 29°C in August.

Precipitation in the bay area is high in the summer season and low in the winter. The typhoon season during September and October brings considerable rainfall as does the seasonal rainy period from June to July. The total number of rainy days is from 100 to 120 each year; the annual precipitation is about 1 600 mm.

Wind conditions above the bay are characterized by a seasonal northerly wind which is predominant in the winter, and a seasonal southerly wind which is due to the Ogasawara high pressure area in the summer.

4.1.1.3 Hydrographic conditions

In general the residual current in the bay is righthanded and the surface water tends to flow out of the bay while the bottom layer of water tends to flow into it (Figure 9 - 1 and 2).

The velocity of the tidal current is rather high in the central area of the bay and low in the coastal regions. A northeasterly current is predominant at high tide, while a southwesterly one prevails at low tide (Figure 10, 1 and 2).

A conspicuous hydrographic feature is the formation of a distinct vertical density stratification during the summer season (Figure 11).

4.1.2 Background and causes of water pollution

Ever since consolidated works were first initiated in Tokyo Bay in 1887, reclamation projects along the coastal regions have been increasing. Unfortunately, in the process of land reclamation, some coastal areas which were excellent fishing grounds right back to the Edo period have gradually been eradicated.

Water pollution first became conspicuous in 1925 and since then has increased in degree and severity. Pollution problems stemming from urbanization frequently occurred even during the prewar period from 1933 to 1936 and caused enough concern to warrant the instigation and establishment of a water pollution control commission. This commission was delegated authority to implement counter-measures for the prevention of water pollution-related damage. Pollution in those days, however, was far less a problem than it is today.

During the period from 1944 to 1948, when the war and its subsequent repercussions were severely felt, the water systems of the Koto district and that of the lower Sumida River became clean enough to be inhabitable by fish and to be suitable for recreational fishing. This was attributed to a decrease in the discharge load of municipal waste water due to destruction of industrial plants as well as residential dwellings. However, serious aggravation of the quality of coastal water accompanied the rapid postwar reconstruction of the Tokyo metropolitan area. Two factors were largely taken as responsible for this condition - the high rate of migration of rural inhabitants into the metropolis and the development of many types of industries - and the problem has been increasing precipitously ever since 1950. Legal disputes focussing on water pollution have been frequent since 1956. Particularly noteworthy was the year 1958, when water pollution of rivers in urban areas was seriously aggravated by a water shortage in the metropolitan area. The result was an outbreak of an offensively odorous gas, particularly in those areas bordering the banks and coastal region of the Sumida River. Not only did the gas give off a highly disagreeable smell, but it also caused corrosion of many structures including culturally precious national treasures of the well-known temples located in the Asakusa area as well as metallic objects including household appliances.

Concurrent with this turn of events, an increased flow of traffic into Tokyo Bay by domestic and foreign vessels as the result of the high tempo of postwar economic growth brought with it deep anxiety over the effects on the local fisheries such as laver culture (Table 9).

A rise in the number of outbreaks of red tide in the bay has been witnessed since 1950. Large scale outbreaks involving practically the entire bay area first occurred in 1954 (Figure 12). The frequency of outbreaks has been highest in the summer season and has tended to increase from year to year during this season (Figure 13). It has been demonstrated that some of the outbreaks have been due to diatoms, but that in more recent years, damage due to flagellates has been on the increase (Figure 14). Typical red tide organisms are given in Figure 15.

4.1.3 Water quality and bottom deposit surveys

In this section discussion focusses on a description of the results of a comprehensive water quality survey undertaken jointly by the Tokyo metropolitan government and those of the Chiba and Kanagawa prefectures during the period between 1970 and 1972.

The water quality of Tokyo Bay is characterized by considerable seasonal variation. As shown by changes in transparency, which is the simplest index of water quality, the water of the bay has been found to be relatively clear during the season of active circulation showing a value of about 3 to 7 m. During the season of reduced circulation, the water has an olive colour, and transparency is less than 1 m. Seasonal variation in transparency is shown in Figure 16, while yearly fluctuation is illustrated in Figure 17.

The distribution of total organic carbon (TOC) of the surface water during the circulating season in February is depicted in Figure 18 which illustrates the following features: TOC values of 1.5 mg C/l at the entrance to the bay, 2 mg C/l at the head, and 3 mg C/l along the coastal areas from Kawasaki to Tokyo. These values reflect the background influx load, while in August, when circulation is less, they are generally two to three times higher than those given for February, e.g. 3 mg/C/l at the entrance to the bay and greater than 6 mg C/l at the head. Chemical oxygen demand (COD) attains a maximum during the stratifying season and declines during the circulating season (Figure 19). Dissolved oxygen (DO) is about 95 percent saturation in all layers during the circulating season; in the season of reduced circulation it is about 200 percent in surface water and lower in the bottom layer.

Measurement of chlorophyll a demonstrates a high concentration of about 70 μg/l during the season of reduced circulation in the surface layer. Phytoplankton were observed to reduce transparency, cause high values in TOC and COD, and to create conditions of supersaturation in DO. This phenomenon typically accompanies water pollution and is attributed to eutrophication. Concentrations of nutrient salts such as total nitrates and phosphates, which induce secondary pollution due to organic matter, are 1.5 ppm and 0.2 ppm, respectively, within the bay; similar values at the entrance to the bay are 0.5 ppm total nitrates and 0.09 ppm total phosphates (Figure 20, 1 and 2). These values are considerably greater than the standard values of 0.2 ppm nitrogen and 0.015 ppm phosphorus, which represent indices for the prevention of red tide outbreaks. They are indicative of conditions best described as super-eutrophication.

A survey of bottom deposits in the bay was conducted during the three-year period from 1971 to 1973. The "mud content ratio" was employed as an indirect index of pollution, since the amount of organic matter increases in the transition of bottom sediments from sandy to clayish composition. The mud content ratio is under 50 percent in all areas of the bay with the exception of the entrance and the off-shore coast of Funabashi which is located at the bay head, and is less than 40 percent in the entire area of the bay head bordered by imaginary lines drawn between the port of Tokyo and Makuhari, and between Point Honmoku and Point Banshu (Figure 21 - 1).

Ignition loss was 5 to 10 percent for both the entrance and area of the bay head, while values between 10 and 16 percent were found for other areas (Figure 21 - 2). Seasonal variations in both mud content ratio and ignition loss were not clearly recognized.

As for sulfide concentration, a restored condition was recognized in October; high concentrations which exceeded 0.5 mg S/g were found in the western half of the bay between the mouth of the Ara River and Point Honmoku, while values of 0.2 to 0.3 mg S/g were detected in other areas including the entrance to the bay (Figure 21 - 3).

These results indicated that pollution of bottom deposits due to organic matter was at a rather high level. It was especially conspicuous during the summer season when the water of the bottom layer was characterized by an oxygen-deficient condition, and practically all areas of the bay were brought into a restored condition. This phenomenon resulted in an expansion of lifeless benthic areas.

Regarding heavy metals, the horizontal distribution of total mercury (T-Hg), cadmium (Cd), chromium (Cr), lead (Pb), and arsenic (As) are shown in Figure 22. T-Hg was detected at concentrations ranging between 0.5 and 1.0 ppm in the western part of the bay from the port of Tokyo to the bay entrance, and in that part of the bay from Yokohama to Kisarazu. However, other areas were not found to be excessively contaminated at high concentrations of T-Hg. The concentration of Cd was 1 to 3 ppm in the western region of the bay head from the mouth of the Ara River to Point Honmoku, and this relatively high level was found to extend out into the area adjacent to Chiba prefecture. The concentration of Cr was greater than 100 ppm in the western part of the bay head, and a high concentration also extended across the bay into the area adjacent to Chiba. Lead was found distributed in all parts of the bay except for the western region at concentrations under 100 ppm. A high concentration of As was recognized in the coastal regions of the bay head from the port of Tokyo to Ichihara. High concentrations exceeding 15 ppm were recognized at the mouth of the Ara

River as well as in the port of Tokyo. Mean concentrations of the five heavy metals detected in sediments sampled from all areas of the bay over the three year survey period are shown in Figure 23.

Results of the survey showed that ignition loss (as an indicator of organic substances in sediments) decreased from 25 percent in the surface deposits to 15 percent in lower layers to a depth of 10 cm; no change in ignition loss was recognized in sediments from layers beneath the upper 10 cm. Concentrations of T-Hg, Cr, Pb and Cd were high in sediment down to a depth of 15 cm, indicative of recent heavy metal pollution.

4.1.4 Changes in fishery yield

Changes in fishery yield during the past several decades are shown in Figure 24 - 1, 2, 3, 4 and 5. Some general tendencies are described in the following paragraphs:

4.1.4.1 Shellfish

In the vicinity of the Haneda-Tama River (Station A), the yield of clam has been decreasing since 1948, and the species has become practically non-existent since 1957. In the area surrounding the mouth of the Ara River (Station B), the yield increased up until 1952 but then decreased significantly from 1957 . The yield of short-necked clam at station A has been increasing since 1948, and reached a maximum at station B in 1952. The species is found in the vicinity of station B at a fairly high density. Oyster yield was practically constant up to 1960, then declined significantly. According to a survey taken in 1960 a large population of ark shell was found inhabiting the bay area, even in the vicinity of the mouth of the Edo River. Up to 1962, the yield was almost constant at a level of approximately 20 000 tons.

4.1.4.2 Squid and octopus

The yield was 300 tons in 1956 but has declined significantly since 1962 and fell to nearly five tons in 1969.

4.1.4.3 Crustaceans

General fluctuations have characterized the yield of these invertebrates. It decreased remarkably from 1961 and crustaceans had almost totally disappeared by 1970. However, as of 1975, they have reappeared around the mouth of the Edo River. As for prawns, over 100 tons were produced up to 1965, but production has decreased since 1967 and has completely ceased at the present time.

4.1.4.4 Fishes

The yield of sardine has tended to decrease since 1958, when tonnage was 3 500. Open ocean species including skipjack, round herring, red sea bream and spanish mackerel practically disappeared in the period between 1961 and 1964; at the same time, fishes of the inland sea including flatfish, gray mullet and goby have maintained nearly constant levels, while the yield of common sea bass has increased.

4.1.4.5 Laver

The yield has fluctuated yearly but is generally on the increase.

4.2 The present state of pollution and fisheries in the Seto Inland Sea

4.2.1 The present state of pollution

The environmental pathway of various pollutants into areas of the Seto Inland Sea has been found to be extremely complicated as shown in the diagram given in Figure 25. Within this region, there are many shoaling beaches and inland bays supporting a population of more than 20 million inhabitants as well as providing a convenient location for the operation of littoral industries. The establishment of industries in this region has been encouraged since 1955. This has resulted in the growth of a heavy chemicals industrial complex during the period of precipitous economic development. Accompanying this period of technological progress, water pollution has increased in the region of the Seto Inland Sea due to the heavy influx of discharged industrial wastes.

Table 10 provides some indication of the trends in water quality which have occurred during the past several decades by comparing the results of recent water quality surveys with that conducted in 1952. As an index of the general state of water pollution, transparency is seen to have decreased over the years, while the total amount of nitrogen has increased. These indices are indicative of the higher level of water pollution in the Seto Inland Sea during recent years.

Regarding pollution counter-measures, strict effluent standards have been established for waters off the littoral industrial zone and along the waterfront areas of large cities largely as a result of the "Water Pollution Control Law" which was enforced in June 1971; moreover, monitoring and surveillance systems have been firmly established. Favourable results stemming from such legislation are presented in Table 11 from which it can be seen that the water quality in the major industrial areas improved following the enforcement of strict effluent regulations.

Prior to the "Water Pollution Control Law" the "Seto Inland Sea Conservation Law" was enacted on 2 November 1973 in an attempt to bring about a halt to further aggravation of the marine pollution situation. The first interim objective has been to reduce the pollution load (measured in terms of chemical oxygen demand) by 50 percent of the 1972 value; the projected date for realization of this goal has been set for November 1976. The prefectures concerned bordering the Seto Inland Sea have been required to establish and/or reinforce effluent standards to achieve this goal. It is hopefully anticipated that the water quality around the waterfronts of the industrial zones will improve once implementation of these counter-measures has been fully realized.

The results of monitoring and surveillance which have provided the groundwork for enactment of environmental quality standards are presented in Table 12. The results indicate that the frequency at which toxic substances have been detected to exceed the standard values have decreased to a level of 0.23 percent in 1973, reflecting annual improvement on a nation-wide basis. In the Seto Inland Sea, the incidences at which pollution guidelines were exceeded have been almost constant and at lower levels than the nation-wide averages during the same years; values were 0.22 percent in 1971, 0.21 percent in 1972 and 0.22 percent in 1973.

Regarding the recent rate of achievement for environmental quality standards in rivers, sea areas, lakes and marshes around the Seto Inland Sea, BOD levels in rivers decreased to 58 percent in 1973 from 64 percent in 1972, while COD levels in the sea areas increased to 83 percent in 1973 from 70 percent in 1971, and were followed by a decrease to 80 percent in 1973. In lakes and marshes COD values have been gradually increasing from 1971, and high achievement rates on the order of 82 percent were attained in 1973, indicating improvement of environmental quality. This may have been partly due to the fact that the amount of water discharged into rivers decreased in 1973 due to the occurrence of a nation-wide water shortage. Moreover, this apparent improvement may have been related to the fact that relatively high rates of achievement have been obtained for lakes and marshes, more of which are formerly listed as water bodies each year. In general, the percentages of water bodies which met the environmental quality standards have recently been high for rivers and sea areas, and low for lakes and marshes.

Table 12 (b) shows the comparison between annual mean values and those of the environmental quality standards for COD and BOD values in each type of water body. As for rivers, the number which met the environmental quality standards rose, while for sea areas the percentages went up to a level of 80 percent in 1972, increasing from 60 percent in 1971 and remaining almost unchanged at 79 percent in 1973. Furthermore, two lakes which had been newly categorized as water bodies in 1973 met the environmental quality standards, and this resulted in an increase in the rate from 0 percent in 1971 to 33 percent in 1973.

A comprehensive water quality survey project was implemented in the Seto Inland Sea area in 1972 in an attempt to clarify the pollution conditions and the processes which have created the situation. Figure 26 shows the horizontal distribution of surface COD in 1972, and Table 13 indicates the changes in the distribution of COD in the Seto Inland Sea area. The percentage of those areas where COD value was under 1 ppm decreased from 1972, while those exceeding 1 ppm increased. In particular, a high percentage (14.1 percent) was seen for bodies of water where values exceed 3.1 ppm. Such areas were not suitable for fisheries. This suggests that still greater efforts are needed to prevent pollution in such areas.

Thus it is apparent that the water quality as represented by COD value has gradually improved at some of the waterfronts of industrial areas in the Seto Inland Sea. However, it is still difficult to predict any improvement on the basis of surveys for environmental quality standards as described above, because of complications such as increases in survey stations, survey frequency, and yearly changes in water quality.

4.2.1.1 Red tides

Data reflecting the number of red tide outbreaks in the Seto Inland Sea is presented in Figure 27. It is evident that the number of cases which have actually resulted in damage to fisheries has tended to decrease since 1971, while the total number of cases is still on the increase. This possibly indicates that eutrophication is still advancing in some areas of the Seto Inland Sea, though the increase in the number of red tide cases reported may be the result of better reporting via a red tide information monitoring network. The accumulation of nutrient salts by bacteria in water bodies tends to accelerate eutrophication which in turn induces secondary pollution due to organic matter caused by abnormal outbreaks of red tide plankters. Table 14 shows the classification of such plankters which were identified in red tide outbreaks during 1974.

4.2.1.2 Polychlorinated biphenyls (PCBs)

The data presented in Table 15 reflect the present state of PCB pollution in coastal waters of the Seto Inland Sea, and demonstrate that these waters are some of the most highly polluted in Japan. The permissible limits for PCBs in fish and shellfish, effluent water and bottom deposits which have been established by the Environmental Agency are less than 3 ppm, less than 0.01 ppm and less than 100 ppm, respectively. Those areas which exceeded these limits included Osaka Bay, Harima Sound, the waterfront at Iwakuni, Beppu Bay and Aita Bay. In those areas where fish were found contaminated with PCBs exceeding the limit of 3 ppm, legislative action prohibited the sale of polluted fish and moreover established a directive whereby industries causing pollution problems would be held liable for the purchase of polluted fish from fishermen. In addition, provisions have been enforced whereby bottom deposits containing PCBs at concentrations greater than 100 ppm become free from pollution through dredging or reclamation operations.

4.2.1.3 Mercury

In the coastal waters of the Seto Inland Sea those areas found to be most heavily polluted with mercury included the sea fronts at Tokuyama, Niihama and Mizushima. A survey revealed that fish and shellfish contained mercury at concentrations exceeding the provisional control limits. It was disclosed that two plants engaged in the production of sodium hydroxide (caustic soda) were located in Tokuyama Bay (the Tokuyama Soda and Toyo Soda Companies). The results of a mercury pollution survey of fish and shellfish indicated

that mantis shrimp which were caught in Tokuyama Bay contained 3.32 ppm total mercury. A comprehensive survey of mercury pollution was implemented in 1973 by the Environmental Agency, and the pollution sources of mercury and its environmental levels in the Seto Inland Sea are presented in Table 16. In the survey, it was discovered that five species of fish including common sea bass, black porgy, kelp greenling, surfperch, and rockfish which were caught in Tokuyama Bay exceeded the provisional standards. As a consequence, fishery operations in the bay have been extensively curtailed through legislative control.

Counter-measure operations for mercury polluted sludges have been classified into two categories according to level of contamination. Sludges contaminated at levels ranging from 16 to 32 ppm are used in land reclamation projects, while those ranging from 15 to 20 ppm are dredged.

4.2.1.4 Heavy metals and oysters

In Hiroshima Prefecture periodic monitoring of heavy metals and bacterial examination of oysters - a popular product of the prefecture - have been carried out since 1950. The programme was initiated to protect public health. Additionally, routine analyses of zinc, chromium, cadmium and mercury in water, bottom sediments and oysters have been conducted since 1968 during the harvesting season in November in all areas of the prefecture where oysters are cultured. The average values of heavy metals detected in oysters from 1968 to 1972 are shown in Table 17. The survey revealed that oysters collected along the eastern coastal region were contaminated with heavy metals at unusually high levels - from 2 to 5 ppm. Announcement of these levels through the news media created considerable concern among consumers regarding the potential health hazard of pollutant metals, and the oyster fishery suffered enormous damage and financial loss.

4.2.1.5 Pollution of bottom sediments

Pollution of bottom sediments in the Seto Inland Sea is considerable. The environmental water quality standards for fishing grounds with respect to sludge are as follows (on a dry weight basis): less than 20 milligrams/gram in COD, less than 0.2 mg/g in sulfides, less than 0.1 percent in n-hexane extracts, and "not detectable" in soluble toxic substances. Marine areas where COD value of bottom deposits exceeded the standard of 20 mg/g included the greater part of Osaka Bay, the east coast and central area of Harima Sound, the central area of Bisan Seto, the entire Hiuchi Sound, Bingo Sound, Hiroshima Bay, the southern part of Suo Sound and the entire Beppu Bay and Uwa Sea. Figure 29 shows values for COD, total sulfide and ignition loss as determined by the Southwest Seas Regional Fisheries Laboratory in October 1972.

4.2.1.6 Oil pollution

Accompanying an increase in the volume of oil transported in the Seto Inland Sea, marine pollution created by unlawful dumping of oil by ocean going vessels, discharge of land-stored petroleum products and leakage or spillage resulting from maritime accidents involving tankers have been steadily increasing and have brought about a serious problem. The number of cases of marine oil pollution has increased yearly from 1969 to 1973 (Figure 30). Examination of the different sea regions which comprise the Inland Sea reveals that the number of cases of marine oil pollution is nearly proportional to the intensity of vessel traffic (Figure 31). The number of cases in regions adjacent to littoral industrial zones was relatively low in 1974. It is also noteworthy that vessels other than tankers showed a rather high incidence of involvement in oil pollution (Figure 32).

On 18 December 1974 an accident at the Mizushima Oil Refinery of the Mitsubishi Co. Ltd. resulted in leakage of about 43 000 kl of type "C" heavy oil from a storage tank. An estimated 7 500 to 9 500 kl inadvertently escaped into the neighbouring waters. The oil slick was widely dispersed in Mizushima Sound from the western part of Harima Sound to Kii Channel, and resulted in extensive damage and loss to local fisheries. Since the accident occurred in a semi-enclosed body of water protected from the open ocean, the oil slicks were eventually washed ashore causing extensive damage to nearshore fisheries such as

seaweed (laver) and yellowtail culture. Furthermore, vertical dispersion of oil into the water and deposition on the bottom caused concern over detrimental effects on the benthic ecosystem. (Supplementary Figure III).

As can be seen from the preceeding discussion, water pollution in the Seto Inland Sea has come to be more of a serious environmental problem due to the effects of secondary factors including pollution stemming from organic matter and accidental oil spillage.

4.2.2 The present state of the seaweed beds in the Seto Inland Sea

The seaweed or kelp beds in the Seto Inland Sea play an important role in marine production; disappearance of such areas of productivity would inevitably result in the extinction of many species of living resources endemic to or those cultivated in the area.

Seaweed beds in the Seto Inland Sea have been decreasing in area yearly. The area of the eel grass ("amamo", Zostera) beds classified according to echo-sounding records prior to 1965, and the rate of reduction up to 1965, are shown in Figure 33. Similar data showing the area of Zostera zones in the different regions of the Seto Inland Sea in 1965 together with area reduction rates between 1965 and 1971 are presented in Figure 34. The decline in the area of these beds has been primarily attributed to reclamation operations for the creation of industrial zones, and secondarily to water pollution caused by sludge during such reclamation work or industrial waste water discharge following reclamation. The magnitude of land reclamation in terms of the area of land reclaimed annually from 1955 to 1970 is shown in Figure 35. The area of land reclaimed in the period 1955 to 1969 in the Seto Inland Sea according to prefectures bordering the Sea is given in Table 18, while Table 19 gives data on the area of land which has been reclaimed in different zones or regions in the Sea up to December 1971. It can be readily seen from these tables that approximately 18 000 ha of land were reclaimed from 1955 to 1969, and the projected plan as of 1 December 1971 involved a total of about 70 000 ha. The total land area involved in these reclamation projects accounts for about 35 percent of the total shallow water fishing grounds in the Seto Inland Sea.

Another aspect of the land reclamation operations is that they are generally carried out in coastal areas and result in the deformation of natural coastlines. The present state of coastline utilization as surveyed by the Environmental Agency in 1974 is presented in Table 20. Of a total 6 500 km of coastline, 19 percent of the coastal shoreline is on the mainland while 26 percent surrounds islands. This indicates that most of the coastline areas intended for reclamation work were completed in 1974.

It is quite obvious that deformation of coastlines eliminated some areas of scenic beauty, and in less aesthetic terms the loss of beaches due to embankments has reduced the capacity to decompose organic matter by inhibiting oxygen dissolution and self-purification processes.

Based on such considerations, it can therefore be seen that the effects of reclamation on the marine environment and marine resources are of tremendous impact and significance. Thus, it goes without saying that extremely careful and prudent evaluation and planning should be given to any proposal concerning land reclamation.

4.2.3 Fisheries and pollution

Among the thousand or so species of living organisms which inhabit the Seto Inland Sea, those of importance to fisheries are the following: about thirty species of fish such as red sea bream, black porgy, Spanish mackerel, anchovy, sand lance, conger eel, gray mullet, rockfish, lizard fish and flatfish; ten species of crustaceans such as prawn and swimming crab; sixteen species of molluscs such as common cuttlefish, Pacific octopus, short-necked clam, and cockle; and "wakame" seaweed.

The fisheries of the Seto Inland Sea can be divided broadly into two types - natural resource and mariculture. The fishery yield in 1972 is shown in Table 21; that for marine fisheries was 25 tons/year/km^2. Adding that derived from mariculture production, the total is about 35 tons/year/km^2. These statistics reflect very high productivity of the Seto Inland Sea in comparison to other marine regions.

In general and simple terms, a high level of water pollution results in decreased yield. When relatively small scale bodies of water such as bay heads, lakes and marshes are badly polluted, living organisms disappear. However, in a relatively large body of water such as the Seto Inland Sea, the increase of water pollution is a more gradual process, although there may be cases of localized rapid advancement. Bodies of water are classified into two categories, oligotrophic and eutrophic, according to concentrations of nutrient salts such as nitrogen and phosphorus. In polluted areas, eutrophication proceeds due to the influx of industrial and residential waste waters. During the incipient stages of eutrophication, basic productivity increases; and as it advances, carnivorous fish decrease in number while herbivorous ones increase. This condition is suitable for the culture of laver, though productivity is occasionally reduced since this condition is also suitable for outbreaks of red tides.

Fisheries production in the Seto Inland Sea has shown a steady increase ever since the late 1920s, and annual yield on the basis of catch statistics reveals steep increases with the exception of a period of stagnation from the mid-1950s (Figure 36). In this regard, however, careful consideration should be given to changes in production composition. For example, catches of red sea bream, sharp-toothed eel, shrimp and swimming crab have suffered drastic declines since 1953 (Figures 37, 38 and 39). Important shoals of these fishes and crustaceans are located in the Seto Inland Sea with the exception of conger eel. A loss of excellent fishing grounds in the shallow areas of the Inland Sea has resulted from water pollution. The decline in populations has been caused by the influx of industrial and resident waste water, sludge sedimentation, and land reclamation.

A tendency has been observed towards increased catches of anchovy, sand lance, flatfish, hairtail and conger eel among fish species; cuttlefish, sea cucumber and short-necked clam among molluscs; and "wakame" seaweed (Figures 37 and 38). This may perhaps be due primarily to increases in nutrients and foods which accompany eutrophication in the Inland Sea. The above-mentioned species are among those which are tolerant of marine pollution, since increases in productivity have been witnessed during times of recent polluted conditions.

Mariculture relies on the productivity of a given marine region as well as on artificial rearing facilities with adequate and sufficient feeding, and it is obvious that yields are ultimately determined by environmental conditions as well as culture techniques. Two examples can be given. The production of laver quadrupled between 1955 and 1970. This was accomplished through the development of culture techniques including artificial spat collection and a floating system together with expansion of culture grounds further offshore to escape the adverse effects of nearshore eutrophication. Similarly, the yield of cultured yellowtail quintupled during the same period, but in recent years has been damaged significantly by large-scale outbreaks of red tide. Programmes and centres for artificial fisheries propagation are considered promising from the standpoint of increasing natural populations of aquatic animals. This method consists of stocking the shallow waters of the Inland Sea with cultured fingerlings, but this technique has also been affected by the reduction of suitable culture grounds.

The total fishery yield in the Seto Inland Sea has not shown any tendency to decline, and has indeed increased, but nevertheless fishery operations in this maritime region have not escaped damage from water pollution and land reclamation. Changes in composition of resources, destruction of fishing grounds, massive fish kills due to red tide, and finally pollution of fishery resources by a variety of industrial pollutants have occurred. This illustrates that at higher levels of pollution, or in relation to certain stocks, the unfavourable aspects outweigh any favourable ones, e.g. due to moderate eutrophication.

The balance of factors ultimately determines the success or failure of fisheries production. It can be predicted that if the degree of water pollution should worsen in the Seto Inland Sea during the ensuing years, the diversity of fisheries will be damaged.

4.2.4 Counter-measures for Seto Inland Sea Pollution

Counter-measures for Seto Inland Sea pollution include the prompt establishment of environmental quality standards, reinforcement of effluent regulations, the rapid development of sewage systems, and expansion of waste oil treatment facilities. The main points are outlined as follows.

4.2.4.1 Designation of water body classification and reinforcement of effluent standards

Seventy-two water areas have been classified by water body category for the application of environmental quality standards. Stricter effluent standards were also established to match the environmental quality standards. On 1 February 1974 the Director-General of the Environmental Agency established an apportionment of pollutant load limits among the eleven prefectural governments which border the Inland Sea based upon the "Seto Inland Sea Conservation Law". This action was taken pursuant to an interim directive whose objective was to reduce the pollution load by 50 percent in terms of chemical oxygen demand (COD). The eleven participating prefectures were required to strengthen or reinforce effluent standards in such a manner that by November 1976 each prefecture could meet the pollution load which it had been assigned. This first interim measure was completed by the end of 1974.

4.2.4.2 Adoption of a system applicable for the construction or remodelling of specified facilities

The "Water Pollution Control Law" provides for a notification system when specified facilities are constructed or remodelled. In the eleven participating prefectures, however, it is necessary to procure the consent and approval of the governor in accordance with the "Seto Inland Sea Conservation Law" as well as assessing the effects upon the environment prior to such action. When an application is submitted for the construction or remodelling of specified facilities, the documents must be open to public inspection at which time opinions can be expressed. This provides a way for local residents to voice an opinion.

4.2.4.3 Policy for the approval and licensing of reclamation proposals

On 18 June 1974 the Environmental Agency called for careful, judicious and prudent consideration on the part of each prefectural governors' office in the issuance of permits for reclamation projects. This policy was based on the "Seto Inland Sea Conservation Law" and took into account general opinion that such projects would further aggravate the pollution situation in the Seto Inland Sea. It includes:

(a) Measures for the conservation of sea areas, natural environment, and marine resources;

(b) Designation of those sea areas where reclamation should be avoided (Figure 40);

(c) Designation of those sea areas where reclamation should be avoided, except under specific conditions.

4.2.4.4 Promotion of pollution control programmes

Pollution control programmes have been established in order to promote counter-measures. To date, eleven regions have had their respective programmes approved and these include Mizushima (first, and in the process of revising), Osaka (second), eastern part of Hyogo, Kitakyushu, Ohita (third), southern Harima, Ohtake, Iwakuni (fourth), and Kobe, Bingo, Sunan, Toyo (fifth). Among other regions, Wakayama, Okayama, Bizen, Hiroshima-Kure, Shimonoseki-Ube, and Kagawa are currently preparing programmes, and Tokushima is in the process of implementing a fact-finding survey.

4.2.4.5 Promotion of sewage treatment facilities

A total of 130 billion yen was invested in 1974 as part of the "Five-year Sewage Plan" for the development of public sewage facilities with special designation of the eleven prefectures bordering the Seto Inland Sea. This amount represents about 28 percent of a total allocation of 470 billion yen under the Plan, and emphasizes the high priority placed on the expansion of facilities for sewage treatment.

4.2.4.6 Development of waste oil treatment facilities

Facilities for the treatment of oily ballast, tank-cleaning water, and bilge have been operating since 1967 at 34 sites in 20 ports located in the Seto Inland Sea.

4.2.4.7 Surveillance and enforcement system for the quality of waste water

The number of "specified" industries according to the "Water Pollution Control Law" located in the eleven prefectures and all the government ordinance cities was 30 492 as of the end of 1973. Spot inspections were made at 12 969 sites, administrative guidance was given in 9 096 cases, directives to improve designated facilities were issued in 392 cases, and provisional measures prohibiting the discharge of waste water from specified facilities were ordered in 58 cases.

4.2.4.8 Monitoring and surveillance of water pollution.

Since the interplay of geographical features, tidal currents and pollution pattern makes it difficult to understand environmental pollution in the Seto Inland Sea, the Environmental Agency has had to conduct water quality and bottom deposit surveys every year since 1972. Development of a red tide forecasting technique, prevention of fishery damage due to red tide, and integrated surveys of regions in which red tide frequently occurs have highlighted the progress of activities undertaken from 1971 to 1973 by and between the Environmental Agency, the Fisheries Agency and the Maritime Safety Agency. Furthermore, another comprehensive survey was undertaken in 1974 to evaluate and predict the effect of the accidental heavy oil leakage in the Mizushima industrial complex upon the environment. This integrated survey was conducted through the joint cooperation of the Environmental Agency, the Fisheries Agency, the Maritime Safety Agency, the Ministry of Construction, the Ministry of Public Welfare and the Ministry of International Trade and Industry.

The Maritime Safety Agency has continued to bolster its pollution prevention capacity by expanding its surveillance and law enforcement staff as well as by reinforcement of its fleet of patrol boats and aircraft in the region of the Seto Inland Sea.

Finally, recent activities include restriction of the ocean dumping of excrement since 1 April 1972, dredging projects involving mercury and PCB-contaminated sludge in waterfront areas, and solidification of a monitoring surveillance system for water quality.

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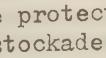
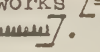
Figure 8 - Diagrammatic representation of the present state of reclamation works along the coastal areas of Kawasaki City, Tokyo, Funabashi City, Chiba City and Ichihara City. Historical development is denoted by cross-sectioned area (1951-1960), horizontal lines (1961-1965), diagonal solid lines (1966-1970), and diagonal dotted lines (1971-1973). Blank bordered areas are those still under construction. Areas enclosed by dotted lines represent dredged areas. Other symbols include those representing breakwaters  , shore protection works  , quays or breakwaters , and wooden stockades . From the Tokyo Metropolitan Harbor Office, March, 1974. 52

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5	Cyclotrichium meunieri	x580
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Data from the Maritime Safety Agency.

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Year	1969			1970			1971			1972			1973			1974		
Description / Region	I	II	T	I	II	T	I	II	T	I	II	T	I	II	T	I	II	T
Hokkaido, coast	12		12	24	6	30	48	7	55	79	12 (2)	91 (2)	91	5 (2)	96 (2)	134	8 (2)	142 (2)
Honshu, eastern coast	11	10	21	19	4	23	82	20	102	149	17 (8)	166 (8)	221	20 (8)	241 (8)	208	16 (2)	224 (2)
Tokyo Bay	51		51	49	7	56	258	1	259	324	11 (3)	335 (3)	240	5	245	246	12 (3)	258 (3)
Ise Bay	25	1	26	19		19	281	58 (55)	339 (55)	235	49 (47)	284 (47)	175	59 (56)	234 (56)	191	43 (36)	234 (36)
Osaka Bay	38		38	41	2	43	146	14 (4)	160 (4)	394	39 (28)	433 (28)	310	70 (67)	380 (67)	269	53 (44)	322 (44)
Seto Inland Sea (excluding Osaka Bay)	63	1	64	114	61	175	253	149 (104)	402 (104)	480	136 (112)	616 (112)	538	129 (94)	667 (94)	531	141 (69)	672 (69)
Honshu, southern coast	24		24	35	4	39	99	15 (9)	114 (9)	104	10 (4)	114 (4)	119	25 (13)	144 (13)	72	13 (8)	85 (8)
Kyushu, coast	32	2	34	32	3	35	77	3	80	114	4 (1)	118 (1)	115	42 (5)	157 (5)	104	41 (6)	145 (6)
Japan Sea, coast	17	21	38	16	4	20	56	54	110	48	17	65	87	22	109	93	33 (2)	126 (2)
Sea areas, southwest										56	5	61	164	23 (1)	187 (1)	137	21 (3)	158 (3)
TOTALS	273	35	308	349	91	440	1300	321 (172)	1621 (172)	1983	300 (205)	2283 (205)	2060	400 (246)	2460 (246)	1985	381 (175)	2366 (175)

Table 2. Frequency of samples exceeding the environmental quality standards for total mercury according to geographical region in Japan.

Metropolis, districts, and prefectures	Name of water body	Sample number	Number of samples [exceeding] the environmental quality standard	[lower than] the environmental quality standard
Hokkaido Pref.	Muka River	7	4	3
Akita Pref.	Yoneshiro River	11	9	2
Gumma Pref.	Vicinity of the Shibu River above the Tone River	15	8	7
Tokyo Metropolis	Edo River	8	7	1
"	Ara River	2	0	2
"	Shin	10	0	10
"	Tama River	5	4	1
"	Port of Tokyo	34	32	2
Yokohama City	Port of Keihin Yokohama	13	10	3
"		3	2	1
Kanagawa Pref.	Morito River	3	2	1
Nagano Pref.	Chikuma River	10	9	1
Gifu Pref.	Suimon River	14	13	1
"		4	3	1
Nagoya City	Oe River	4	3	1
"	Port of Nagoya	35	34	1
Niigata Pref.		15	14	1
Mie Pref.	Hanyu River	4	1	3
Osaka District		6	3	3

Table 2 (cont)

Kyoto City	Tenjin River	1	0	1
"	Nishitakase River	1	0	1
Osaka District	Sea areas of the Sennen headland	22	21	1
Hiroshima Pref.	Sea areas of the Otake headland	10	9	1
"	Sea areas of the Onomichi headland	3	2	1
Kagawa	Gobou River	5	4	1
SUB-TOTAL	25 bodies of water	267	211	56
Yamagata Pref.	Port of Sakata	13	12	1
"	Sea area of the Sakata headland	19	18	1
Toyama Pref.	Port of Toyama	3	2	1
"	A channel connecting to the Port of Toyama	7	3	4
Kyushu (5 prefectures)	Ariake Sea	128	126	2
"	Omuta River	1	0	1
"	Yasuhiro Sea	82	78	4
"	Mina River	2	1	1
"	Euchi River	1	0	1
"	Port of Minamata	6	3	3
"	Amakusanada Shimofukaezu River	2	1	1

Table 3. Regions which Require(d) Sediment Removal Operation as a Countermeasure of Mercury Pollution.

PREFECTURE	NAME OF WATER BODY	HG (PPM) IN SEDIMENT min	max	av	REMOVAL STD (PPM)	ACTION TAKEN
Hokkaido		0.03	38.74	5.839	25	Under critical survey
	Muka R.	0.09	249.82	46.980	25	"
	Shimizu R.		384.25		25	"
	Toyomae R.		218.53		25	"
	Aino R.	0.33	52.71	19.256	25	"
Gumma	Vicinity of the Shibu R. above the Tone R.	0.02	164.00	18.279	25	Project completed
Chiba	Port of Chiba (off Ichihara)	0.07	181.69	21.131	10	Removal operation in progress
"	Port of Chiba (off Kitasodeura)	0.13	23.70	2.730	10	Project completed
Tokyo Metropolis	Lower Sumida R. at Okubashi	2.30	180.00	25.950	25	Under planning
Kawasaki City	Keihin channel, near Central Chemical Co.	1.10	17.50	8.242	7	Project completed
"	Keihin channel, near Showa Denko Co.	2.20	207.70	76.240	7	"
Nagano	Sewage of Okaya City	0.38	95.00	47.690	25	"
Gifu	Western main drainage channel (including Ogaki channel)	13.00	180.00	66.250	25	"
Nagoya	Oe R.	59.00	627.20	301.510	25	Removal operation in progress
Mie	Tanshyo R.	3.5	110.0	35.875	25	Project completed

Table 3. (cont.)

Osaka	Torikai iro	1.31	75.00	24.657	25	Project completed
"	Kanou iro	2.93	1560.00	531.418	25	"
Hyogo	Main Port of Takasago	0.18	34.10	7.324	25	"
"	Mouth of the Shyoka R	4.70	47.00	25.658	25	"
Tokushima	Vicinity of the town of Mizui on the Naka R.	0.19	34.00	9.921	25	Under critical survey
Kagawa	Port of Sakaide	0.21	61.00	10.080	40	Under planning
Kitakyushu C.	Dokkai Bay	0.76	34.40	7.850	30	Projected completed
Oita	Upper Nizu R. at Unabarabashi	0.22	47.00	9.267	25	Under planning
Yamagata	Port of Sakata	0.04	171.00	9.00	28	Under preparation for removal operation
Toyama	Port of Toyama, a channel connecting with	0.09	100.00	37.00	30	Project completed
"	Koyake R.	0.03	220.00	21.60	25	"
Yamaguchi	Port of Tokuyama	0.07	31.59	4.63	15	Under preparation for removal operation

Table 4. Execution of self-imposed control upon the taking of fish polluted with PCBs.

Geographic region	Enforcement date of self-imposed control	Objective fish species
Tokyo Bay, northern part	Dec. 28, 1972	Striped mullet Sea bass
Seki R. system	Oct. 2, 1972	All species
Naoetsu waterfront	Dec. 25, 1972	All species
Tsuruga Bay	Jun. 2, 1973	All species
Kobe City, waterfront vicinity	Jun. 5, 1973	"Konoshiro", *Konosirus punctatus* Mackerel
Himeji City, waterfront vicinity	Jun. 5, 1973	Sea bass "Konoshiro" Striped mullet
Takasago City, waterfront vicinity	Jun. 5, 1973	All species
Iwakuni City, water front vicinity	Jun. 4, 1973	Striped mullet Conger eel Bitterling "Konoshiro"
	Aug. 27, 1973	"Hiiragi" "Shimaisaki", *Therapon oxyrhynchus*
Magara R*	Aug. 21, 1974	"Nigoi" [carp] Catfish
Kyoto area (Uji R. system)	Jun. 18, 1973	Common minnow Cruscian carp
Seta R.	Jun. 14, 1973	Common minnow
Lake Biwa	Jun. 14, 1973	Common minnow Catfish
Oi R.	Feb. 20, 1973	Eel
Lake Shinji*	Jul. 11, 1972	Corbicula
Tenryu R.*	Jun. 3, 1974	Dace
Sai R.*	Jun. 3, 1974	Dace

Data from the Fisheries Agency. Geographic regions marked with an asterisk denote those where self-imposed control has resulted from prefectural surveys.

Table 5. Results of a nation-wide survey on PCB pollution in water, 1972.

AREA	PREFECTURE	NO. OF SAMPLES	NO. WITH PCBs	AV. (ppb)	MAX-MIN
(1) Rivers	Hokkaido	6	2	2.5	2 - 3
	Tokyo	18	1	0.5	0.5
	Yamanashi	6	2	0.7	0.6 - 0.8
		6	6	0.9	1.3.-16.3
	Gifu	5	5	1.5	0.7 - 2
		4	2	0.7	0.6 - 0.8
		1	1	1	1
	Shizuoka	1	1	2	2
	Aichi	4	2	1.1	0.9 - 1.2
	Osaka	2	1	0.5	0.5
		1	1	0.5	0.5
	Hyogo	3	3	5	3 - 6
	Tokushima	14	11	2.0	1.3 - 4.2
	Fukuoka	3	1	3	3
		3	1	0.7	0.7
		1	1	0.9	0.9
	Oita	6	2	1.0	0.6 - 1.4
		6	2	2.8	2.4 - 3.2
	TOTAL	90	45		
(2) Sea Areas	Yamaguchi	134	4	1.3	0.6 - 2.9
	Tokushima	19	4	1.1	0.9 - 1.4
	Kumamoto	1	1	0.6	0.6
		1	1	0.7	0.7
	TOTAL	155	10		
(3) Drainage channels	Iwate	1	1	10	10
		1	1	2	2
	Miyagi	1	1	20	20
		1	1	30	30
	Fukushima	1	1	3	3
		2	1	0.9	0.9
	Niigata	3	2	2.1	0.6 - 3.6
		2	2	36.5	19 -54
	Fukui	2	1	1	1
	Gifu	3	1	9	9
		9	4	2.1	0.7 - 6
		8	2	5	4 - 6
	Shizuoka	2	1	0.5	0.5
		1	1	6	6
		1	1	17	17
	Aichi	1	1	0.6	0.6
		1	1	0.6	0.6
	Kyoto	4	1	1	1
	Tokushima	1	1	1	1
	Kagawa	3	3	28	3.6 -76
	Kumamoto	2	2	0.8	0.5 - 1
		1	1	0.7	0.7
	Miyazaki	2	2	6	1.9 -10
	TOTAL	53	33		

Data from Environmental Agency

Table 6. Results of a Nation-wide Survey on the Quantities of PCBs in Sediments. (1972)

	Prefecture	Area	Number of samples	Average	Range (max-min)
[A]	Shizuoka	Tagonoura	9	59.8	7.5 - 130
	Aichi	Gomeiyosui	5	107.3	18.3 - 300
		Gamagori City	26	26.8	0.1 - 170
		Azumao R.	3	65.9	0.7 - 150
		Sana R.	5	40.6	0.9 - 100
	Tokushima	Yoshinaga	5	81.8	0.02- 386
[B]	Iwate	Iwai R.	3	54.6	54.6
	Niigata	Ogisone R.	6	34.3	1.9 - 62
	Fukui	Tsuruga Port	9	29.6	2 - 65
		Shono R.	6	17.7	0.4 - 55
	Gifu	Arata R.	5	35	15 - 80
	Hyogo	Shoge R.	18	21.2	0.7 - 55
	Nara	Noto R.	2	25.6	0.1 - 51
	Miyazaki	Hitotsuse R.	29	6.7	0.01- 56

Data from the Environment Agency. Bracketed "A" are those areas where PCB concentrations exceeding 100 ppm have been found; "B" denotes those areas where concentrations were 50 to 100 ppm.

Table 7. Regulations on the Use of Agricultural Chemicals (As of Jan 15, 1975)

REGULATION ON USE	AGRICULTURAL CHEMICALS	ENFORCEMENT DATE
Designated as potentially "residual" due to adsorption or absorption in agricultural products	Lead arsenate	May 1, 1971
	Endrin	"
Deisgnated as potentially "residual" in soil	Dieldrin	"
	Aldrin	"
Designated as potentially "residual" in water	Telodrin	"
	Endrin	"
	Benzoepin	"
	PCP herbicide	"
	Rotenone	"
Prohibited	Organic mercury (excluding those for seed sterilization	Mar 1970
	DDT	May 1, 1971
	TEPP	Jun 1, 1971
	Methyl parathion	"
	Parathion	"
	BHC	Dec30, 1971
	Heptachlor	Aug 9, 1972
	2,4,5-T	Apr 6, 1971
	Organic mercury for seed sterilization	Oct29, 1973

Data from the Environment Agency

Table 8. Changes in yields of some major fisheries (1960, 1965, 1970, 1973).

	YIELD (1000 tons)				
	1960	1965	1970	1973	%
Ocean Fisheries					
Open ocean fishery	1,456	1,733	3,429	3,963	37.0
Off-shore fishery	2,111	2,787	3,275	3,944	36.0
Coastal fishery	2,250	1,861	1,891	1,815	17.9
Aquaculture (marine)[1]	380	549	790		7.4
Inland water fishery[2]	113	119	114		1.1
Inland water aquaculture	33	48	64		0.6
TOTAL	6,129	6,908	9,318	10,690	100.0
Whaling (heads)		20,395	16,251	11,268	

Data from the "Production of Fisheries and Aquaculture Yearbook," 1974. Superscript "1" denotes mariculture of oyster, laver (Porphyra), pearls, and yellowtail; "2" denotes rivers and lakes.

Table 9. Damages to Cultured Laver ("nori") Caused by Oil Pollution in Tokyo Bay (1967-1972).

DATE	LOCATION	SOURCE	DAMAGES IN 1000 YEN
1967 Nov 13-27	Off Funabashi City	Waste oil from factories	448,200
Dec 7- 9	Off Kisarazu City	"	313,862
1968 Jan 8	"	"	104,395
Jan 30-31	Off Funabashi City	Spillage of fuel oil	523,668
Nov 29	Off Kisarazu City	Waste oil	25,434
Dec 4	"	"	6,360
Dec 6- 8	Coast from Sodegaura to Kisarazu City	Spillage of oil by tanker collision	393,021
1969 Feb 12	"	Waste oil	73,100
Mar 6	Kisarazu City	Foul-smelling sludge from fuel refinery	31,000
Mar 7	Futsu City	Spillage of fuel oil from an iron factory	49,419
1970 Apr 10	Sodegaura	Alkyl benzene	43,725
1971 Dec 4	Kisarazu City	Fuel oil	791,960
Dec 21	Tateyama City	Fuel oil	13,000
1972 Jan 16	Futsu City	Fuel oil	8,500

Data from the Environmental Agency.

Table 10. Pollution Trends in the Seto Inland Sea During the Past Several Decades

	UNITS	1952	1972
Transparency	(m)	8.78	6.33
NH_3-N	(μg-at/l)	2.39	3.62
NO_2-N	"	0.30	0.84
NO_3-N	"	1.03	2.83
PO_3-P	"	0.46	0.54

Data from Governors' Conference on Environmental Protection. Values represent means of all measurements taken during water quality survey in the Seto Inland Sea.

Table 11. Water Quality of the Major Industrial Areas in the Region of the Seto Inland Sea.[1)]

	COD (ppm)[2)]			
VICINITY	Osaka	Kobe	Mizushima	Tokuyama
SAMPLING STN.	Port of Osaka	Kobe-Ohashi	Port of Mizushima	Sennoshima
1970	4.8	1.3[3)]	2.7	5.1[4)]
1973	3.4	0.8	1.5	2.6
1974	2.3	1.6	1.3	2.3

1) Data from the Environment Agency

2) Average yearly value

3) Value in 1971

4) Value in 1967

Table 12. Surveillance Results of Environmental Quality Guidelines in the Seto Inland Sea and Nation-wide.

[a] Incidences at which guidelines were exceeded for health categories.

REGION	YEAR	NO. OF SAMPLES EXAMINED (E)	NO. WHICH EXCEEDED GUIDELINE LEVEL (F)	RATIO F/E (%)
Seto Inland Sea	1971	28,393	63	0.22
	1972	44,432	92	0.21
	1973	49,660	112	0.22
Nation-wide	1971	89,074	504	0.57
	1972	167,368	476	0.28
	1973	181,072	411	0.23

[b] Percentage of those areas which conformed to the environmental quality guidelines.

	Seto Inland Sea			Nation-wide
AREA	1971	1972	1973	1973
River	45	46	47	53
Lake	0	0	33	30
Sea	60	80	79	84

Data from the Environmental Agency

Table 13. Percentages of COD Area Distribution in the Seto Inland Sea (1972 to 1974).

RANGE OF COD LEVEL [PPM]	1972	1973	1974
‹1	27.7	27.3	23.9
1.1 - 2.0	43.7	39.9	45.3
2.1 - 3.0	15.6	22.7	16.7
›3.1	13.0	10.1	14.1

Data from Environmental Agency. Values were taken in May of each year.

Table 14. Red tide plankters which appeared in the Seto Inland Sea during outbreaks in 1974.

Noctiluca	*Haplodinium*
Skeletonema	*Thalassiosira*
Gymnodinium	*Gyrodinium*
Olithodiscus	*Cosinodiscus*
Prorocentrum	*Peridinium*
Mesodinium	*Nitzschia*
Ceratium	*Fibrocapsa*
Heterosigma	*Tricodesnium*
Eutreptilla	*Rhodomonas*
Leptcylindras	*Asteromonas*
Cheatoceras	*Pyramimonas*
Gonyaulax	*Polyblepharides*

Table 15. Localities of the Seto Inland Sea where concentrations of PCBs detected in fish exceeded the allowable limit of 3 ppm.

LOCATION OF CATCH	SPECIES OF FISH	LEVEL OF PCBs (ppm)
Osaka Bay, Southern Coast	Mackerel	5
" , off Kobe	Conger eel	8
	Kelp greenling	4
Harima Nada, off Takasago	Gray mullet	6
	Konoshiro	6
Hiroshima Bay, off Iwakuni city	Common sea bass	3
	Yellowtail	4
Beppu Bay, estuary of the Oita River	Eel	43
	Young bass	3

Data from an investigation of the actual state of PCB pollution, conducted by the Environmental Agency and Fisheries Agency in 1972.

Table 16. Pollution Sources of Mercury and its Environmental Levels in the Seto Island Sea

Pollution Source and Environment	Off Tokuyama	Off Niihama	Off Mizushima
Source of Mercury Pollution	Tokuyama Soda Co. Toyo Soda Co.	Sumitomo Chemical Co.	Kato Denka Co. Ryonichi Co. Okayama Kasei Co.
	Engaged in production of caustic soda by a mercury electrolysis process.		
Total Amount of Mercury Utilized (tons)	1,261,800	32,900	612,800
Amount of Mercury Consumption (tons)	380.8	191.2	30.1
Amount of Mercury Discharged into the Sea (tons)	6.64	0.7	0.76
Fish & Shellfish	II	I	I
Water	I	I	I
Sediment	II	I	I

I - Mercury concentration lower than guideline level (0.5 ppm)
II - Mercury concentration exceeding guideline level

[Data from Environmental Agency]

Table 17. Average Values of Heavy Metals in Oysters From Hiroshima Prefecture (from 1968 to 1972).

HEAVY METAL	CONCENTRATION (ppm)
Arsenic	0.45 - 1.84
Copper	15.4 - 28.3
Lead	0.1 - 0.4
Zinc	213 - 641
Cadmium	0.3 - 1.7
Chromium	0.02 - 0.05
Mercury (total)	< 0.02

Table 18. Area of Reclaimed Land in the Seto Inland Sea According to Prefecture (1955-1969).

PREFECTURE	AREA (hectares)
Wakayama	567.0
Osaka	2,631.6
Hyogo	2,725.6
Okayama	4,504.0
Hiroshima	1,890.2
Yamaguchi	973.3
Tokushima	118.0
Kagawa	1,667.9
Ehime	518.3
Fukuoka	726.0
Oita	1,316.9
Total	17,575.0

Table 19. Area of Reclaimed Land in the Seto Inland Sea According to Zone. Projected area of reclamation as of Dec 1, 1971.

ZONE	AREA (hectares)
Kii Channel	14
Osaka Bay	4,003
Harima Nada	2,904
Bisan Seto	4,133
Hiuchi Nada	1,943
Aki Nada	795
Iyo Nada	1,209
Suho Nada	54,400
Total	69,401

Table 20. Coastline Utilization of the Seto Inland Sea (1974)

PREFECTURE	COASTAL SHORE LINE						SUB-TOTAL		TOTAL
	NATURAL		SEMI-NATURAL		ARTIFICIAL				
	Main	Isl.	Main	Isl.	Main	Isl.	Main	Isl.	
Wakayama	44	29	20	--	55	--	119	29	148
Osaka	3	--	--	--	123	--	126	--	126
Hyogo	72	220	155	30	35	14	262	264	526
Okayama	101	175	60	20	152	10	313	205	518
Hiroshima	31	359	68	204	270	179	369	742	1111
Yamaguchi	248	267	206	35	293	65	747	367	1114
Tokushima	48	53	43	10	27	0	118	63	181
Kagawa	74	182	46	31	155	73	275	286	561
Ehime	373	377	303	136	215	48	891	561	1452
Fukuoka	25	11	13	0	194	0	232	11	243
Oita	224	32	150	17	114	2	488	51	539
Total	1243	1705	1064	483	1633	391	3940	2579	6519
Percentage	19.1	26.2	16.3	7.4	25.0	6.0	60.4	39.6	100.0

Data from the Environmental Agency

Table 21. Production of Major Fishery Resources in the Seto Inland Sea (1972).

RESOURCE	PRODUCTION (10,000 tons)
Fish	25.3
Shrimp	5.5
Shellfish	12.1
Seaweed	0.7
Coastal Culture	
Laver ("nori")	2.1*
Oyster (without shell)	2.6
Yellowtail	0.6
Seaweed ("wakame")	1.5

*billion sheets
Statistics from the Ministry of Agriculture and Forestry

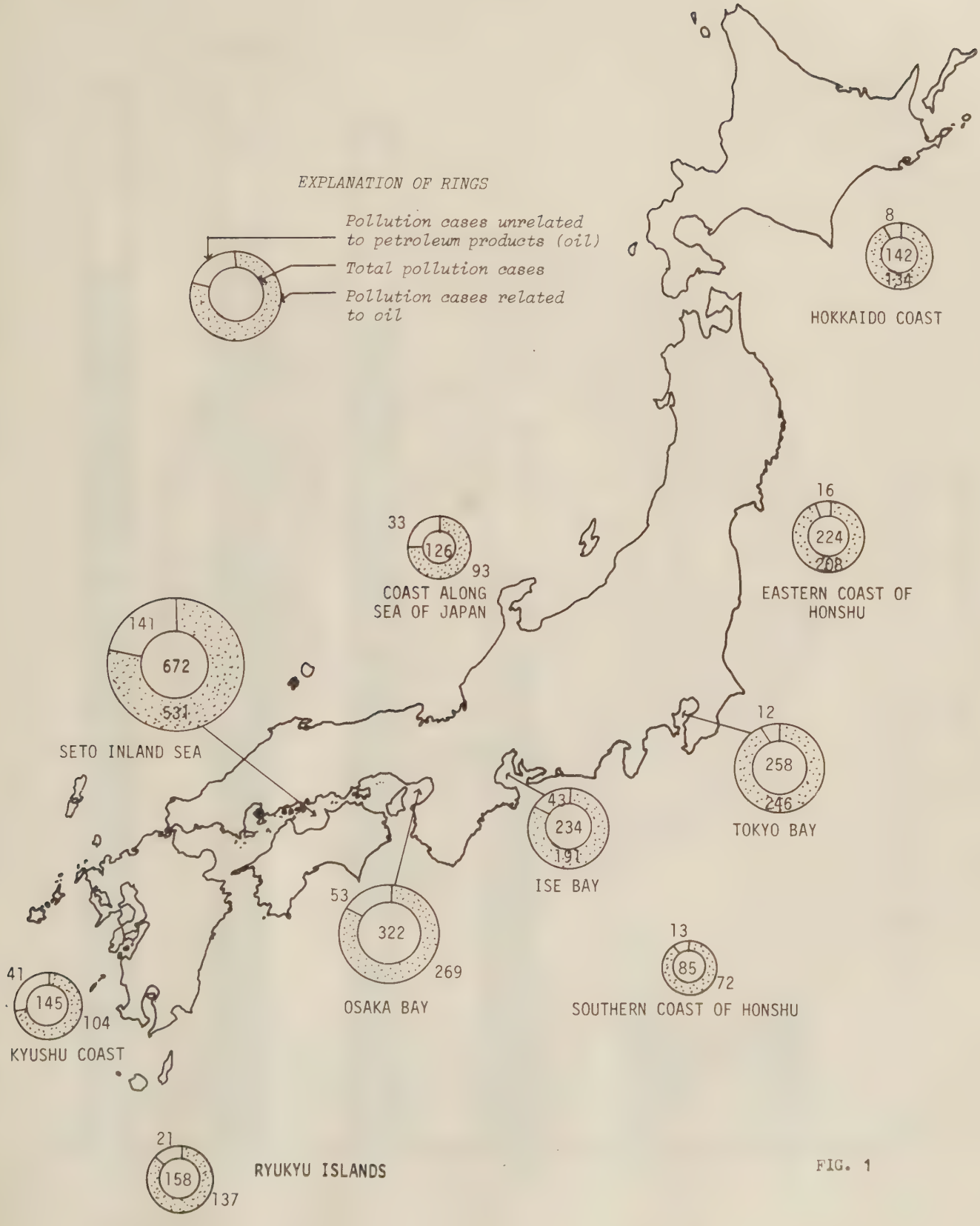

EXPLANATION OF RINGS
Pollution cases unrelated to petroleum products (oil)
Total pollution cases
Pollution cases related to oil
8
142
134
HOKKAIDO COAST
16
224
208
EASTERN COAST OF HONSHU
33
126
93
COAST ALONG SEA OF JAPAN
141
672
531
SETO INLAND SEA
12
258
246
TOKYO BAY
43
234
191
ISE BAY
53
322
269
OSAKA BAY
13
85
72
SOUTHERN COAST OF HONSHU
41
145
104
KYUSHU COAST
21
158
137
RYUKYU ISLANDS

FIG. 1

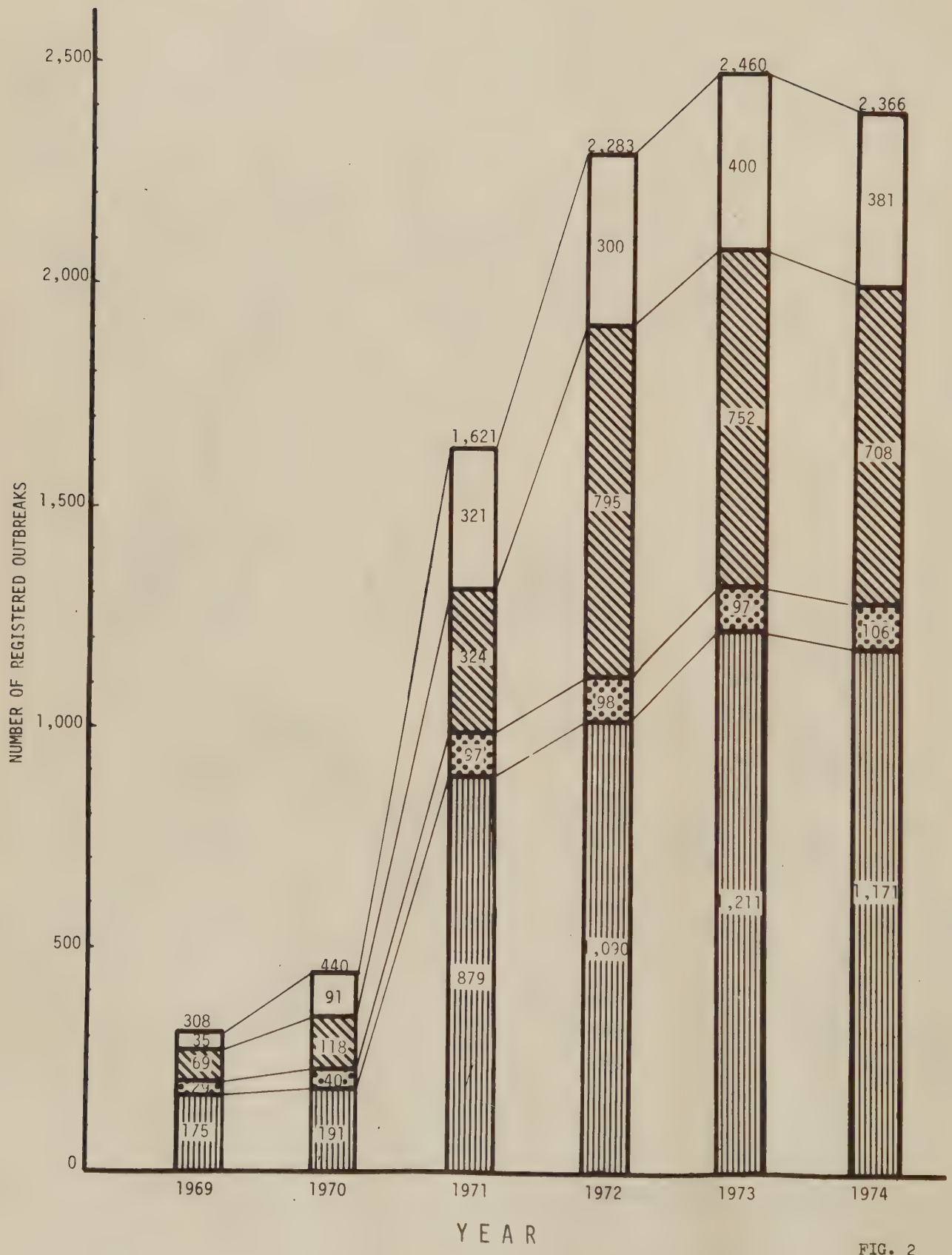

NUMBER OF REGISTERED OUTBREAKS
2,500
2,000
1,500
1,000
500
0
1969
1970
1971
1972
1973
1974
YEAR
308
35
69
24
175
440
91
118
40
191
1,621
321
324
97
879
2,283
300
795
98
,090
2,460
400
752
97
,211
2,366
381
708
106
1,171

FIG. 2

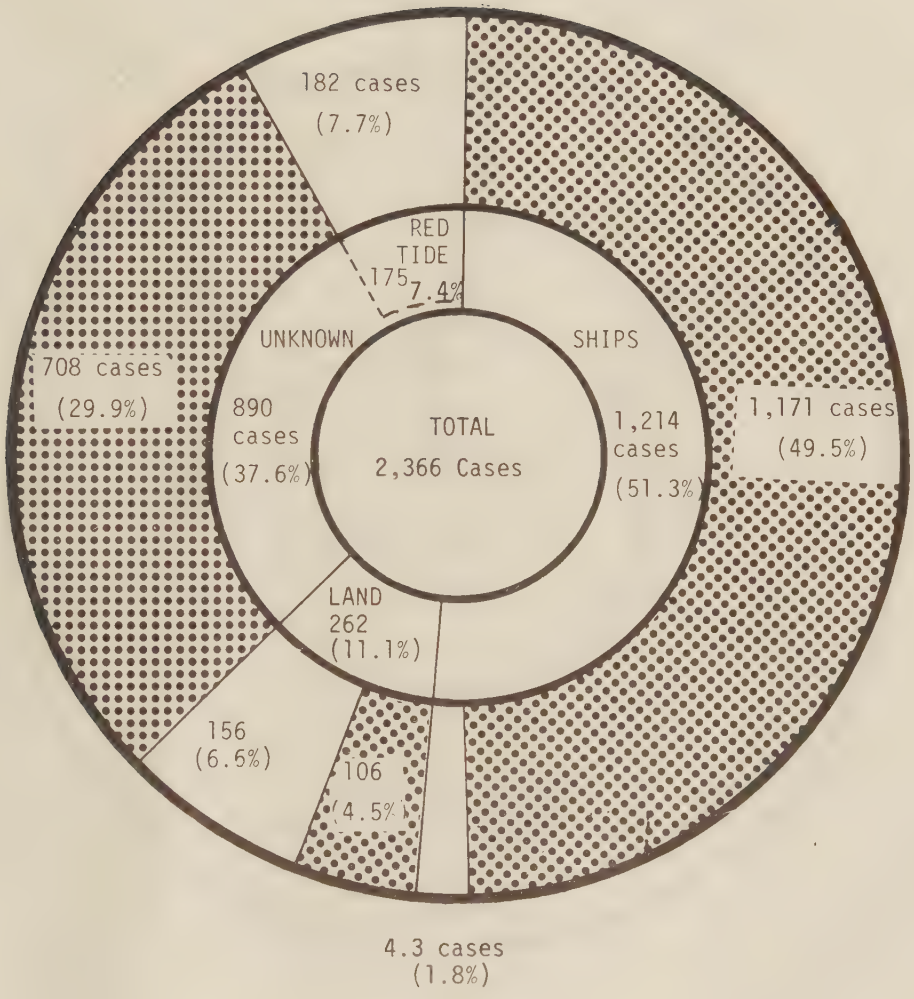


FIG. 3. OUTBREAKS OF MARINE POLLUTION CLASSIFIED ACCORDING TO POLLUTION SOURCE AND TYPE. STIPPLED AREAS OF OUTER RING INDICATE OIL-RELATED POLLUTION; UNSTIPPLED AREAS DENOTE POLLUTION UNRELATED TO PETROLEUM. (1974) [FROM THE MARITIME SAFETY WHITE PAPER, 1975].

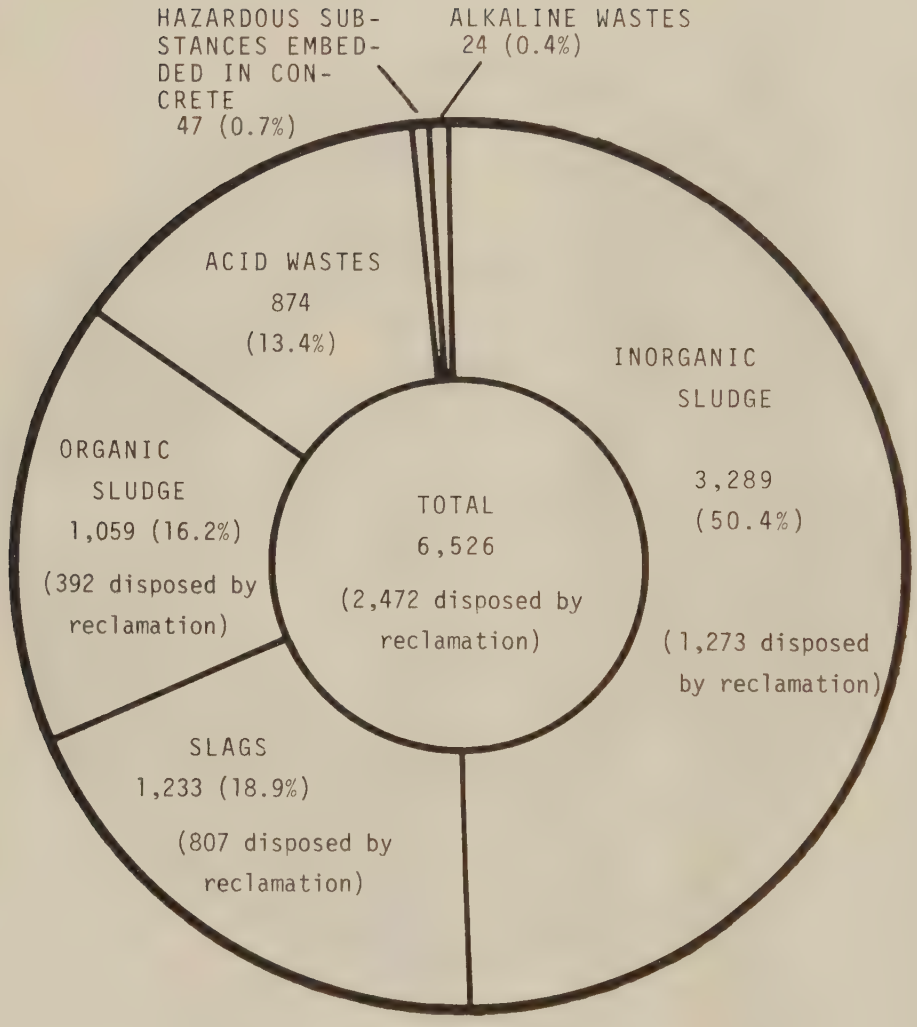


FIG. 4. THE STATE OF DISPOSAL OF INDUSTRIAL WASTES BY MEANS OF DUMPING VESSELS (1974). NUMERALS ARE EXPRESSED IN UNITS OF ONE THOUSAND TONS. AMOUNTS OF INDUSTRIAL WASTES USED FOR LAND RECLAMATION ARE CITED IN CERTAIN CASES. [FROM THE MARITIME SAFETY WHITE PAPER, 1975].

FIG.5

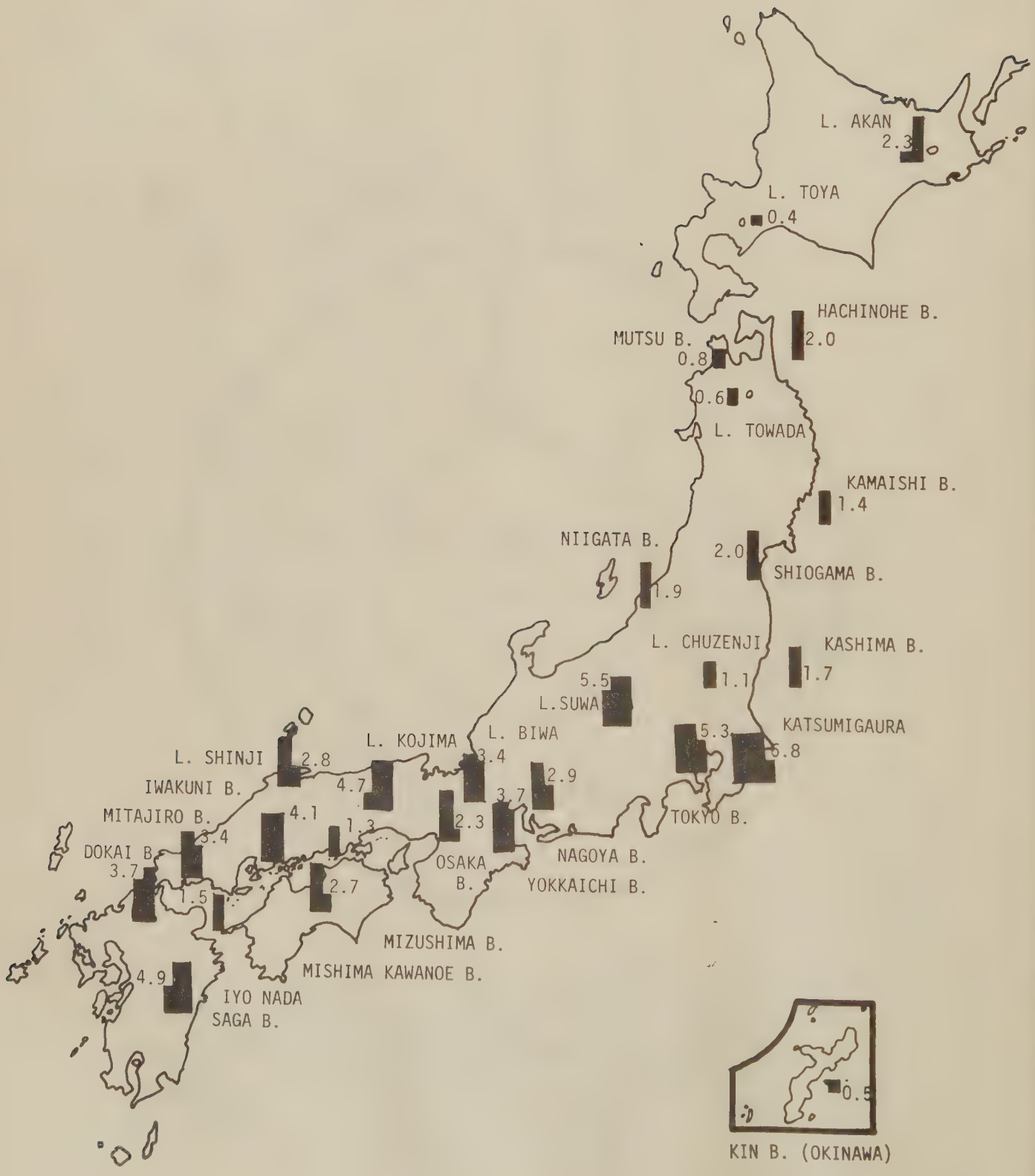

L. AKAN
2.3
L. TOYA
0.4
HACHINOHE B.
2.0
MUTSU B.
0.8
0.6
L. TOWADA
KAMAISHI B.
1.4
NIIGATA B.
2.0
SHIOGAMA B.
1.9
L. CHUZENJI
KASHIMA B.
1.1
1.7
5.5
L. SUWA
5.3
KATSUMIGAURA
5.8
L. KOJIMA
L. BIWA
3.4
L. SHINJI
2.8
2.9
IWAKUNI B.
4.7
3.7
MITAJIRO B.
4.1
1.3
2.3
TOKYO B.
3.4
DOKAI B.
3.7
OSAKA B.
NAGOYA B.
2.7
1.5
YOKKAICHI B.
MIZUSHIMA B.
MISHIMA KAWANOE B.
4.9
IYO NADA
SAGA B.
0.5
KIN B. (OKINAWA)

FIG. 6

FIG. 7. MAP ILLUSTRATING WATER DEPTH OF TOKYO BAY AND SURROUNDING GEOGRAPHICAL FEATURES.

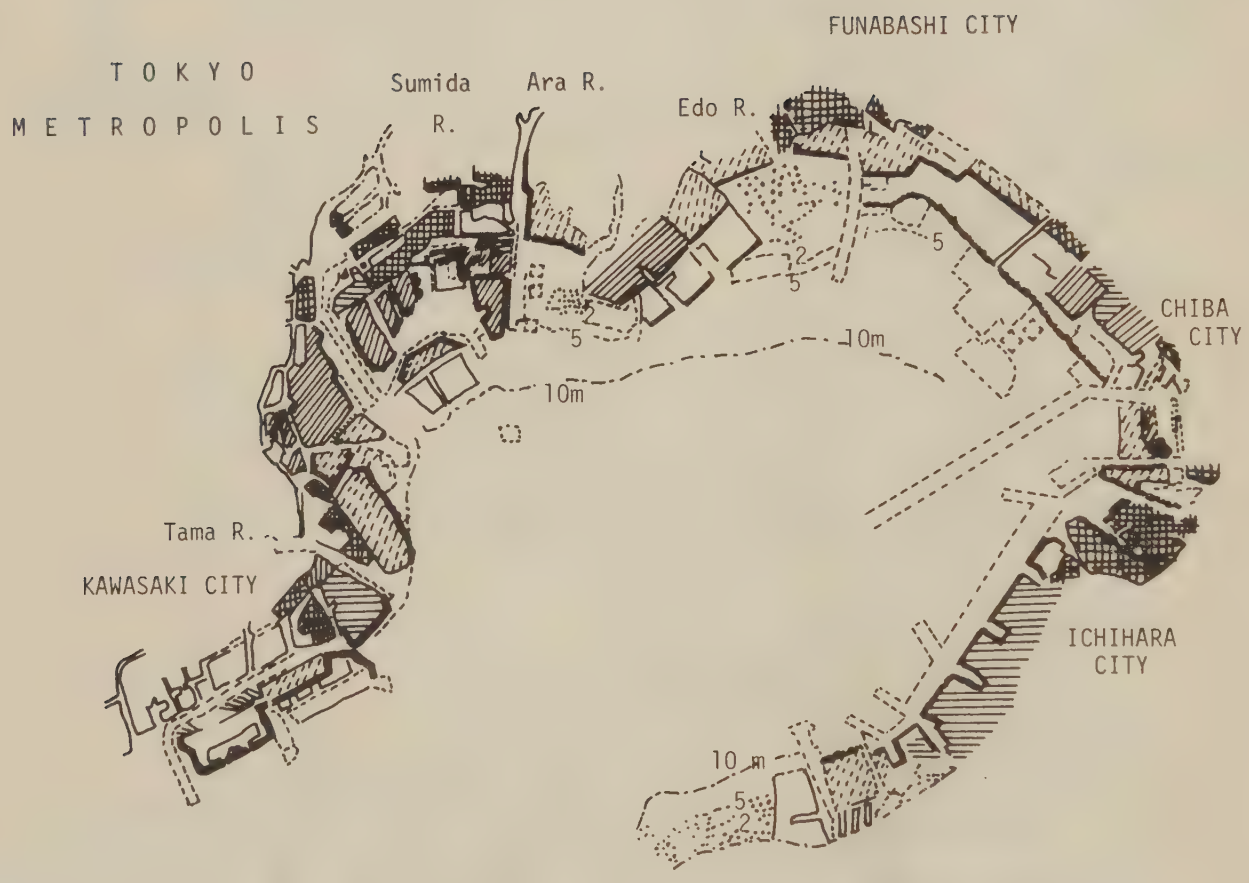


FIG. 8. DIAGRAMMATIC REPRESENTATION OF THE PRESENT STATE OF RECLAMATION WORKS ALONG THE COAST OF KAWASAKI, TOKYO AND CHIBA. YEARS DURING WHICH WORK WAS CONDUCTED IS DENOTED BY CROSS-SECTIONED AREA (1951-1960), HORIZONTAL LINES (1961-1965), DIAGONAL SOLID LINES (1966-1970), AND DIAGONAL STIPPLED LINES (1971-1973); BLANK BORDERED AREAS ARE THOSE UNDER CONSTRUCTION. AREAS ENCLOSED BY DOTTED LINES REPRESENT DREDGED AREAS. OTHER SYMBOLS INCLUDE THOSE FOR BREAKWATER [▬▬], SHORE PROTECTION WORKS [═══], QUAY OR BREAKWATER [——], WOODEN STOCKADE [▬▬]. From the Tokyo Metropolitan Harbor Office, March, 1974.

TOKYO METROPOLIS
SHINAGAWA
CHIBA
KAWASAKI
YOKOHAMA
KISARAZU
YOKOSUKA
KURIHAMA
FUTTSU
KANAYA
-40'
-30'
-20'
-10'
UNDER 10 cm/sec
10 - 15 cm/sec
16 - 20 cm/sec
ABOVE 20 cm/sec

FIG. 9-1

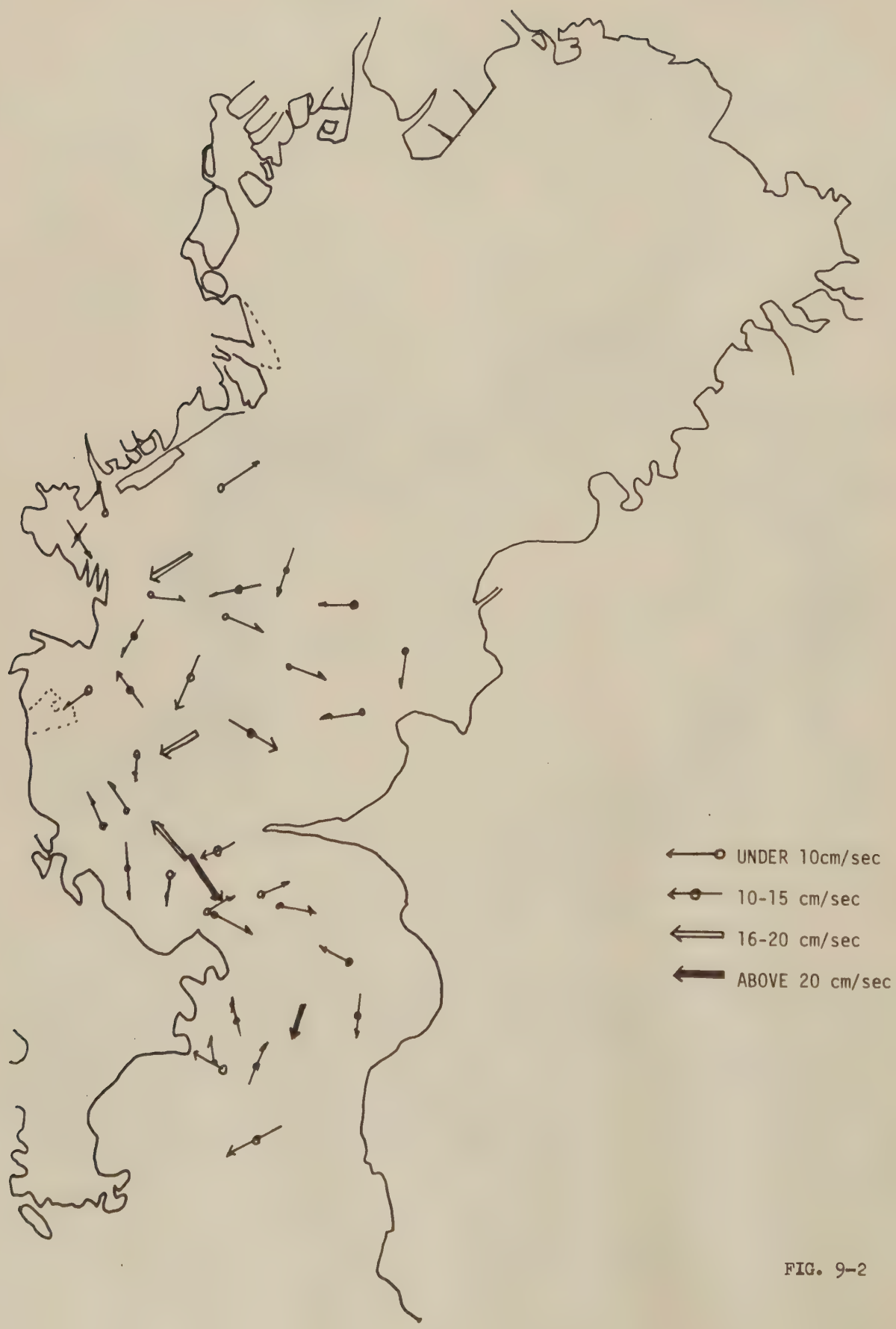


FIG. 9-2

FIG. 10-1

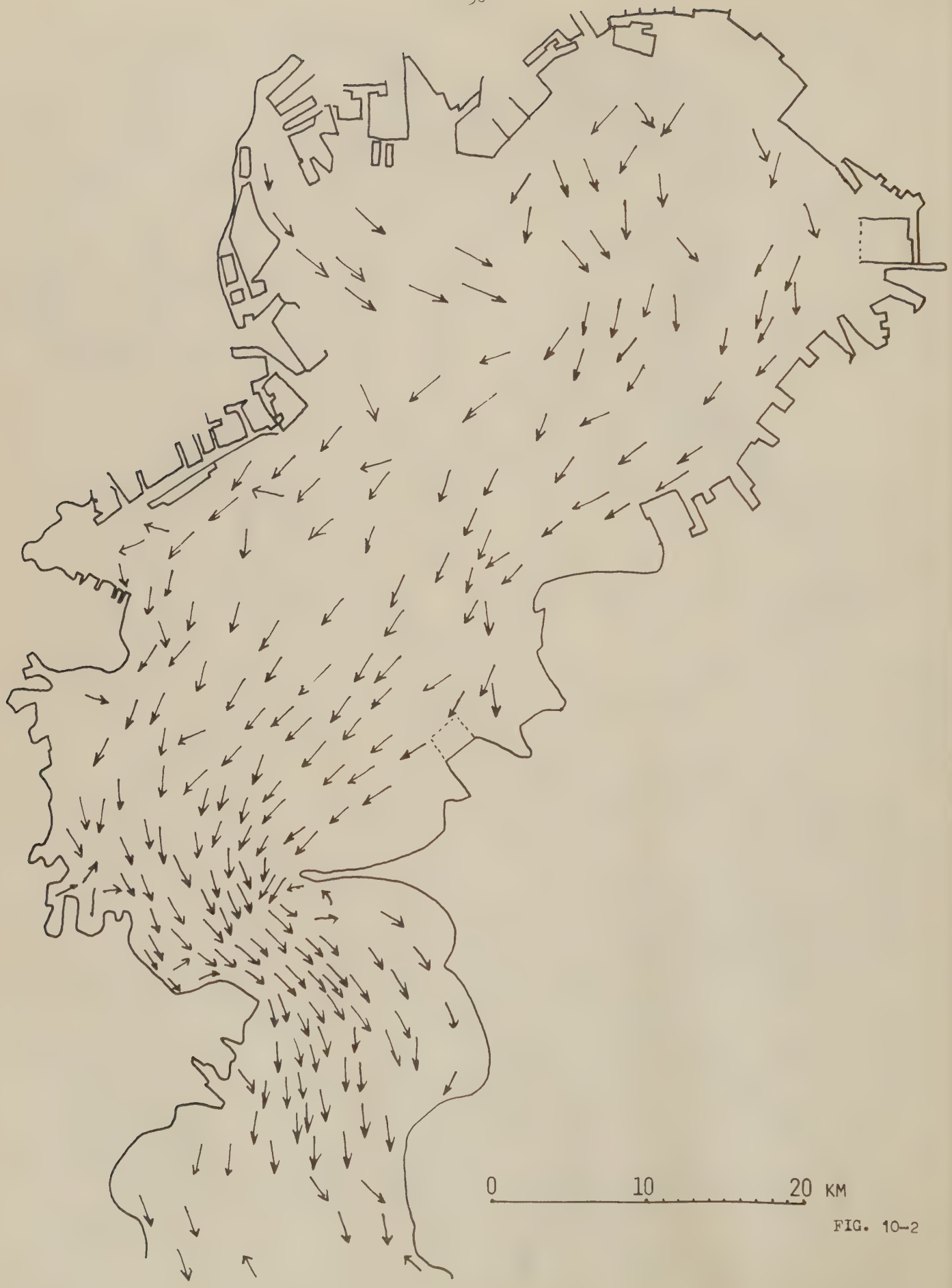


FIG. 10-2

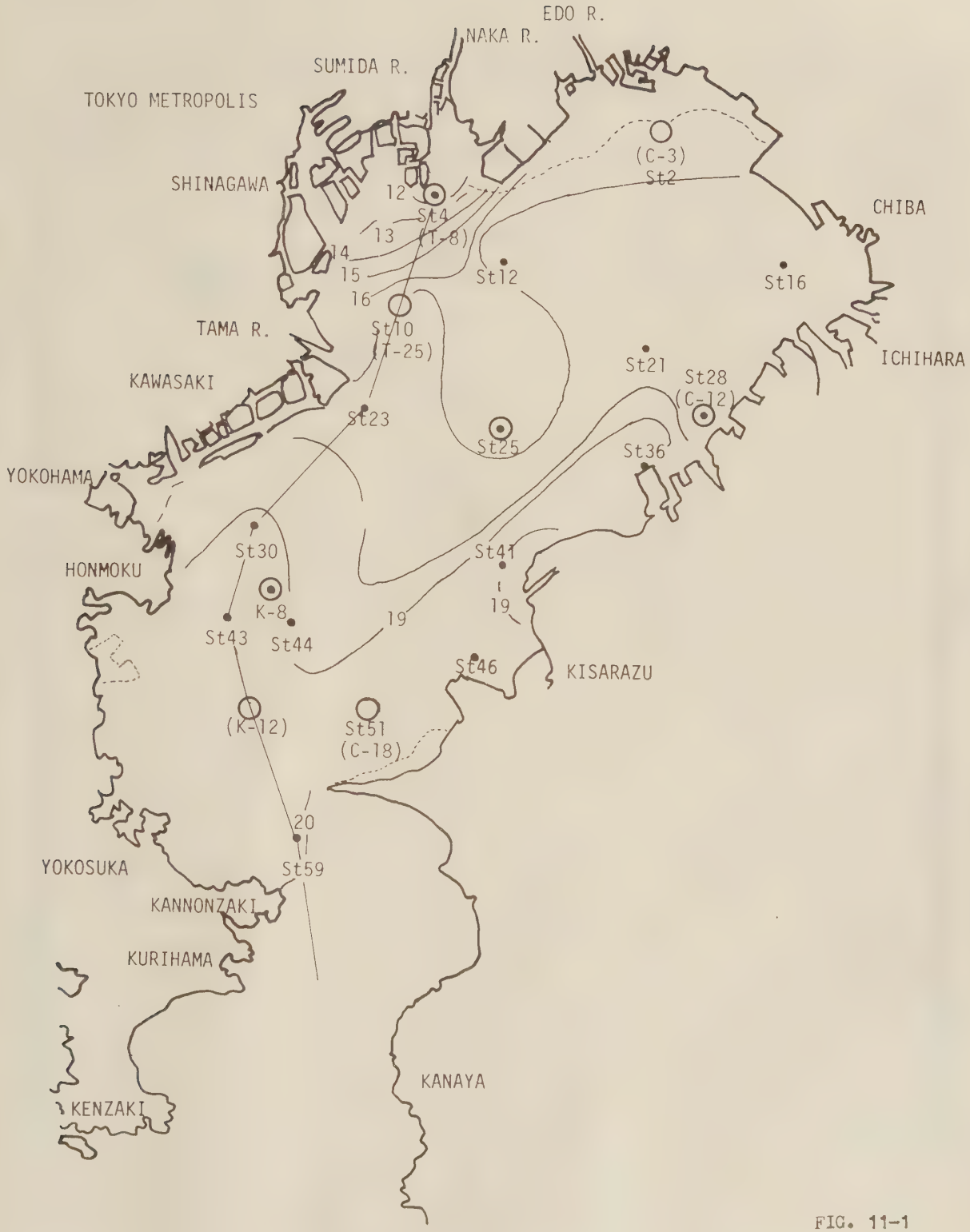

EDO R.
NAKA R.
SUMIDA R.
TOKYO METROPOLIS
SHINAGAWA
(C-3)
St2
CHIBA
12
St4
(T-8)
13
14
15
16
St12
St16
TAMA R.
St10
(T-25)
ICHIHARA
St21
St28
(C-12)
KAWASAKI
St23
St25
St36
YOKOHAMA
St30
St41
HONMOKU
K-8
19
19
St43
St44
St46
KISARAZU
(K-12)
St51
(C-18)
20
YOKOSUKA
St59
KANNONZAKI
KURIHAMA
KANAYA
KENZAKI

FIG. 11-1

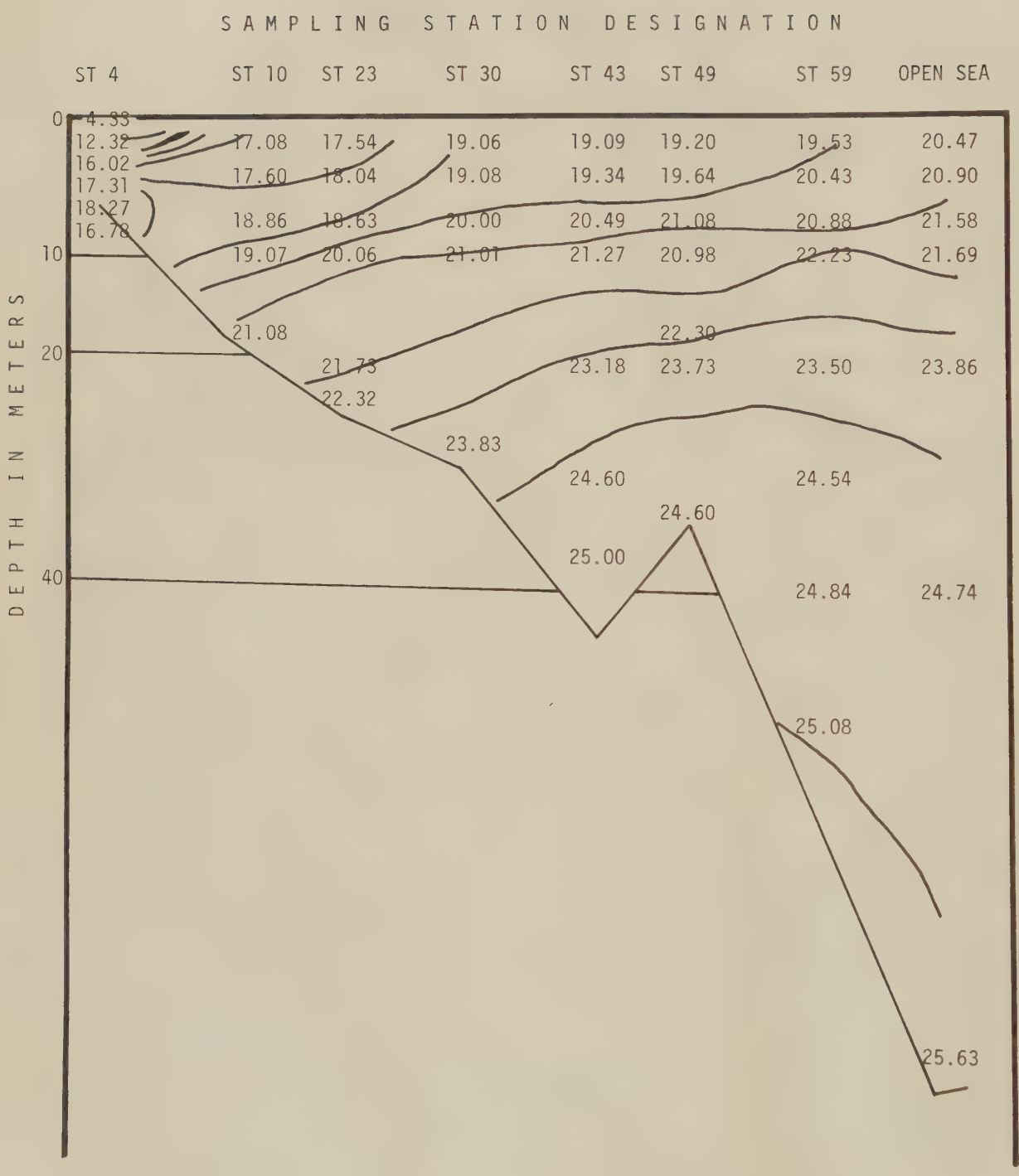

SAMPLING STATION DESIGNATION
ST 4
ST 10
ST 23
ST 30
ST 43
ST 49
ST 59
OPEN SEA
DEPTH IN METERS
0
10
20
40
4.33
12.32
16.02
17.31
18.27
16.78
17.08
17.54
19.06
19.09
19.20
19.53
20.47
17.60
18.04
19.08
19.34
19.64
20.43
20.90
18.86
18.63
20.00
20.49
21.08
20.88
21.58
19.07
20.06
21.01
21.27
20.98
22.23
21.69
21.08
22.30
21.73
23.18
23.73
23.50
23.86
22.32
23.83
24.60
24.54
24.60
25.00
24.84
24.74
25.08
25.63

FIG. 11-2

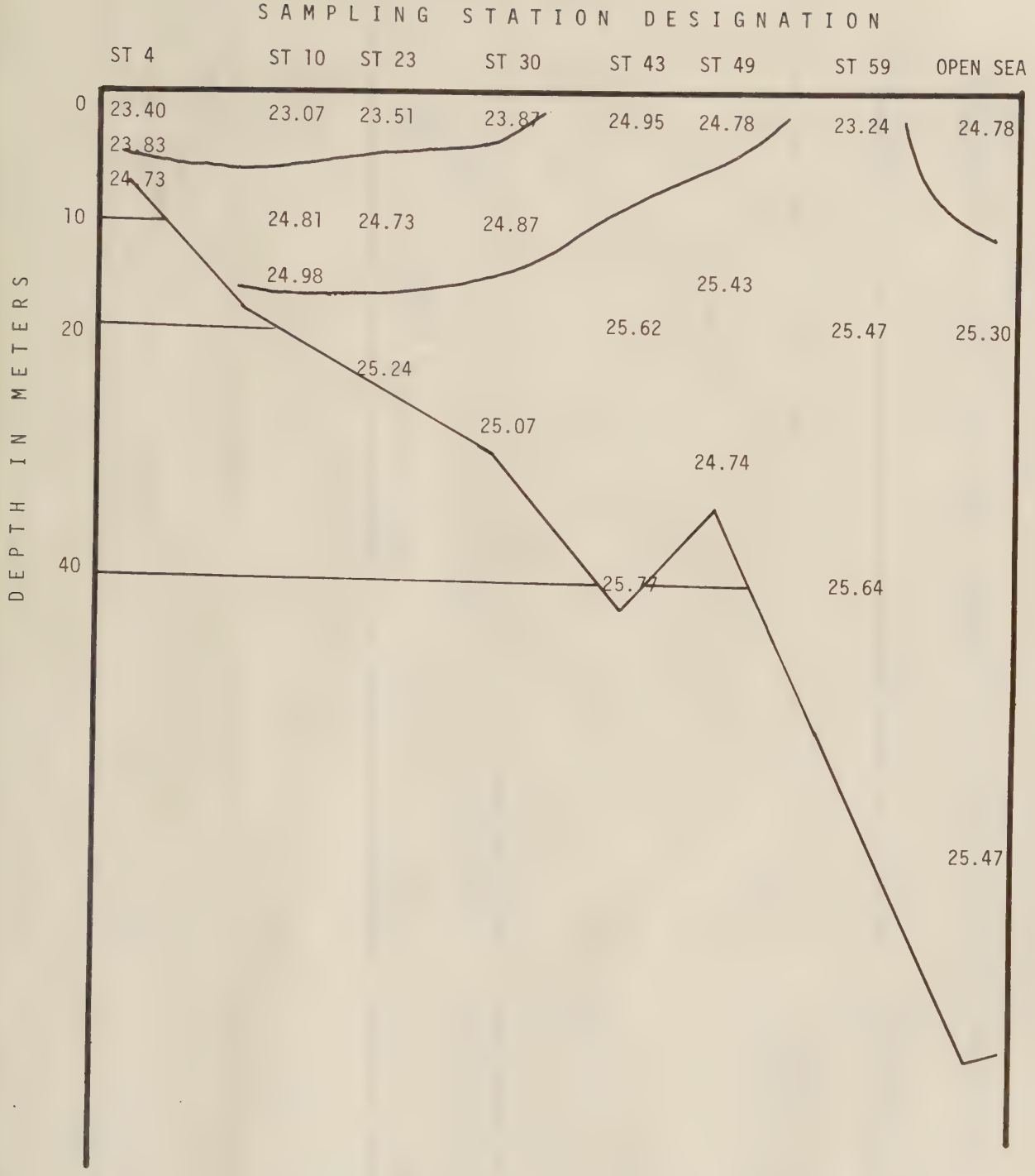

SAMPLING STATION DESIGNATION
ST 4
ST 10
ST 23
ST 30
ST 43
ST 49
ST 59
OPEN SEA
DEPTH IN METERS
0
10
20
40
23.40
23.83
24.73
23.07
23.51
24.95
24.78
23.24
24.78
24.81
24.73
24.87
24.98
25.43
25.62
25.47
25.30
25.24
25.07
24.74
25.64
25.47

FIG. 11-3

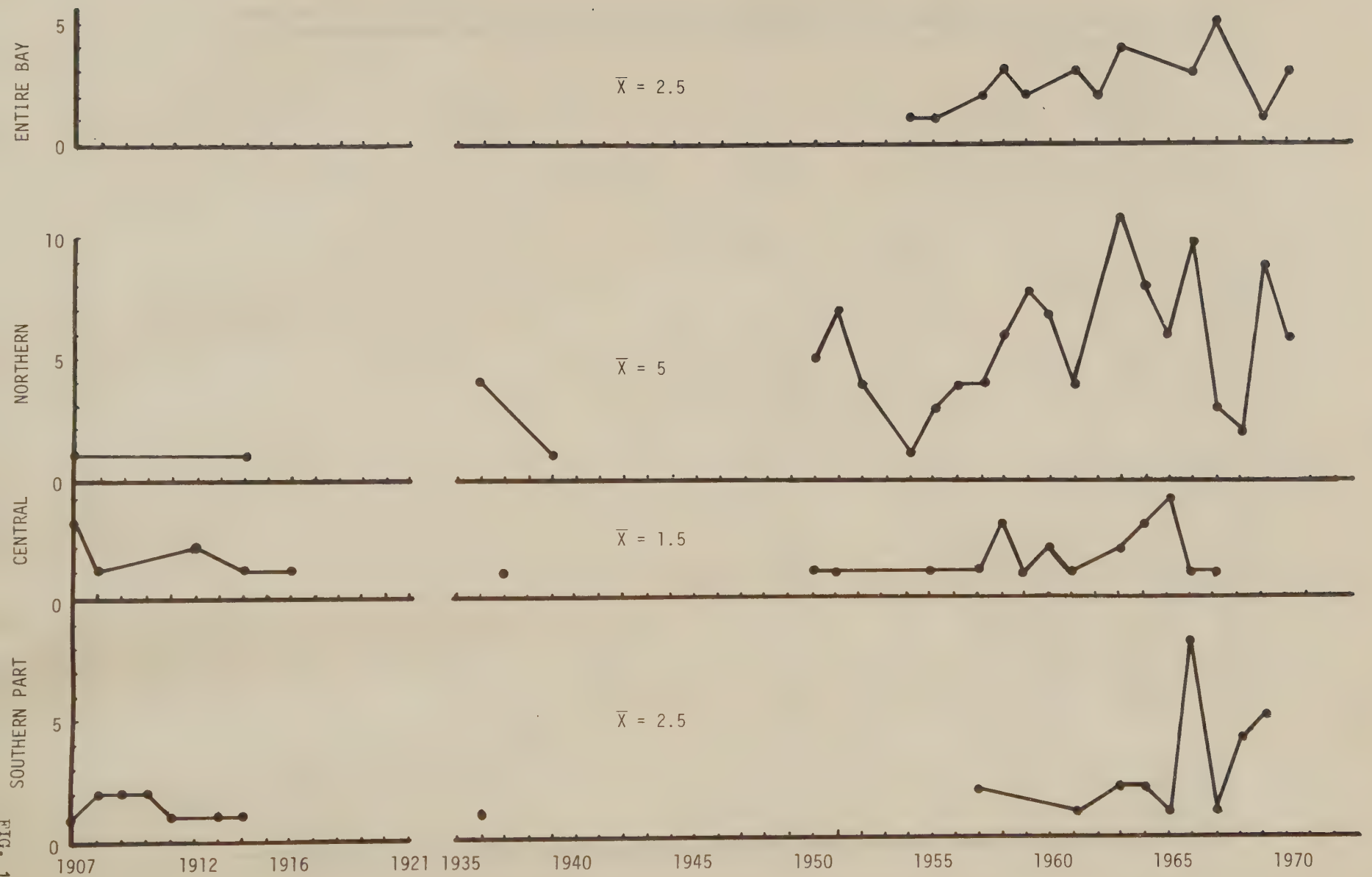

ENTIRE BAY
5
0
$\overline{X}$ = 2.5
NORTHERN
10
5
0
$\overline{X}$ = 5
CENTRAL
0
$\overline{X}$ = 1.5
SOUTHERN PART
5
0
$\overline{X}$ = 2.5
1907
1912
1916
1921
1935
1940
1945
1950
1955
1960
1965
1970

FIG. 12

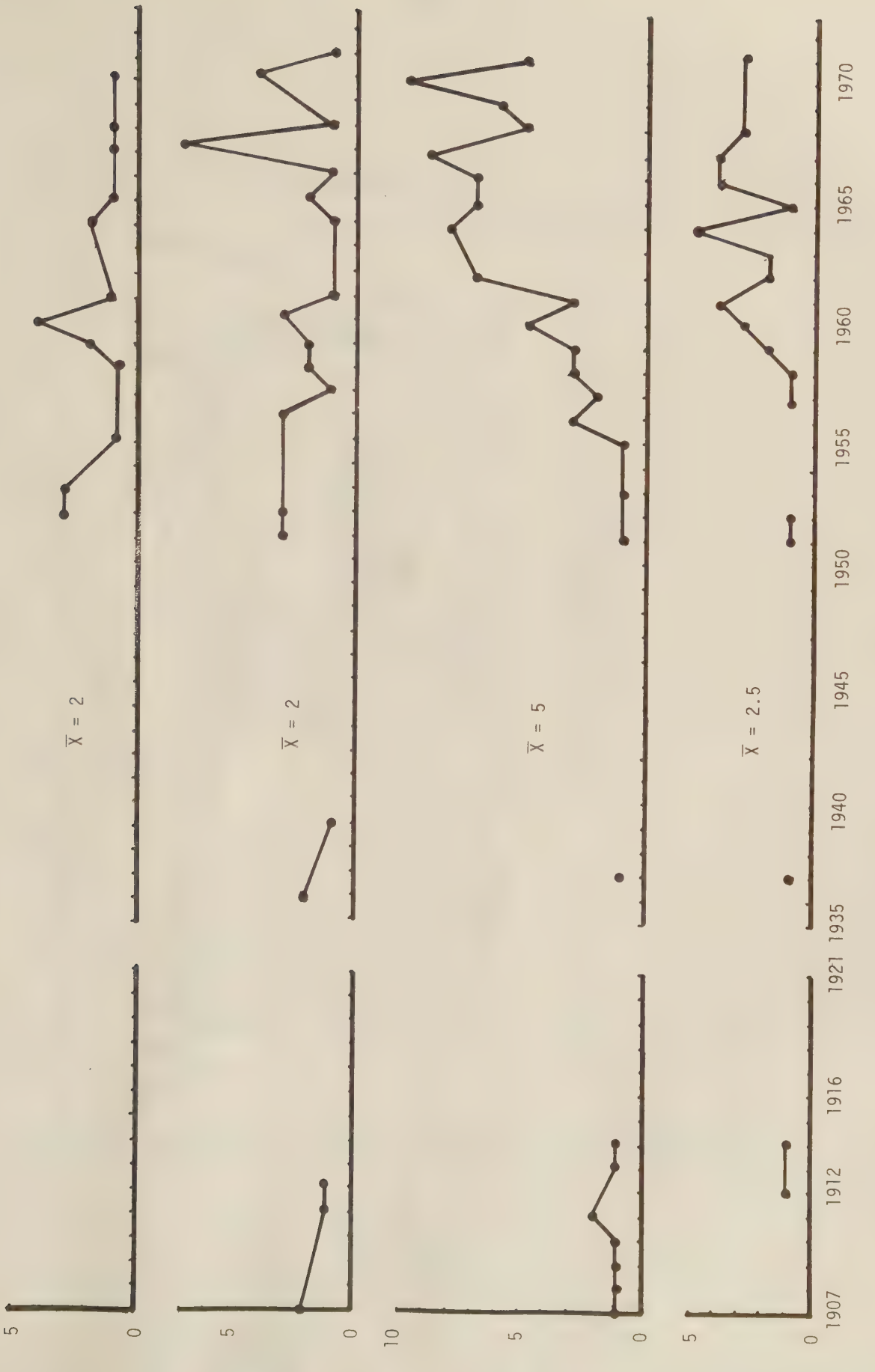

WINTER
AUTUMN
SUMMER
SPRING
5
0
10
$\overline{X}$ = 2
$\overline{X}$ = 2
$\overline{X}$ = 5
$\overline{X}$ = 2.5
1907
1912
1916
1921
1935
1940
1945
1950
1955
1960
1965
1970

FIG. 13

NUMBER OF RED TIDE SPECIES
15
10
5
0
1907
1912
1917
1922
1935
1940
1945
1950
1955
1960
1965
YEAR
$\bar{X}$ = 5

FIG. 14-1

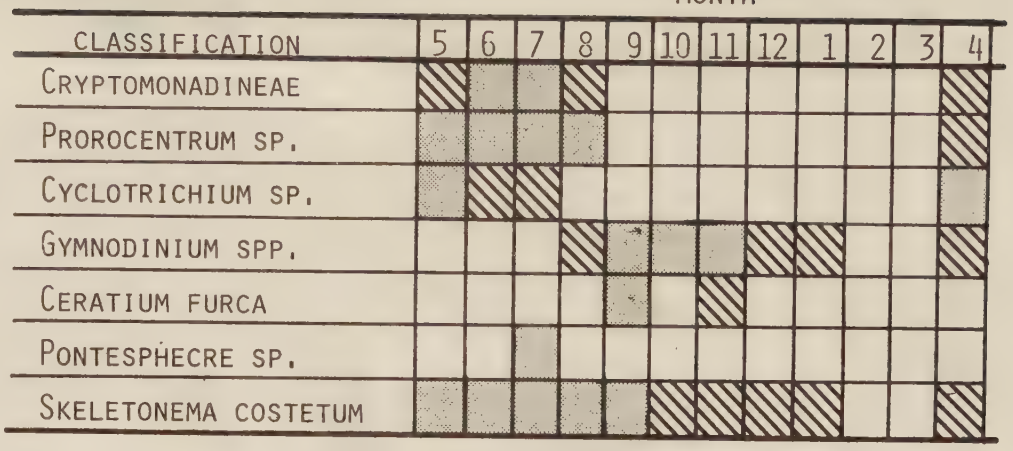


FIG. 14 - 2. SEASONAL VARIATION IN THE DENSITY OF RED TIDE ORGANISMS IN TOKYO BAY. A RED TIDE CONDITION IS DENOTED BY THE DARKENED AREAS; THE NORMAL CONDITION IS GIVEN BY DIAGONAL LINES.

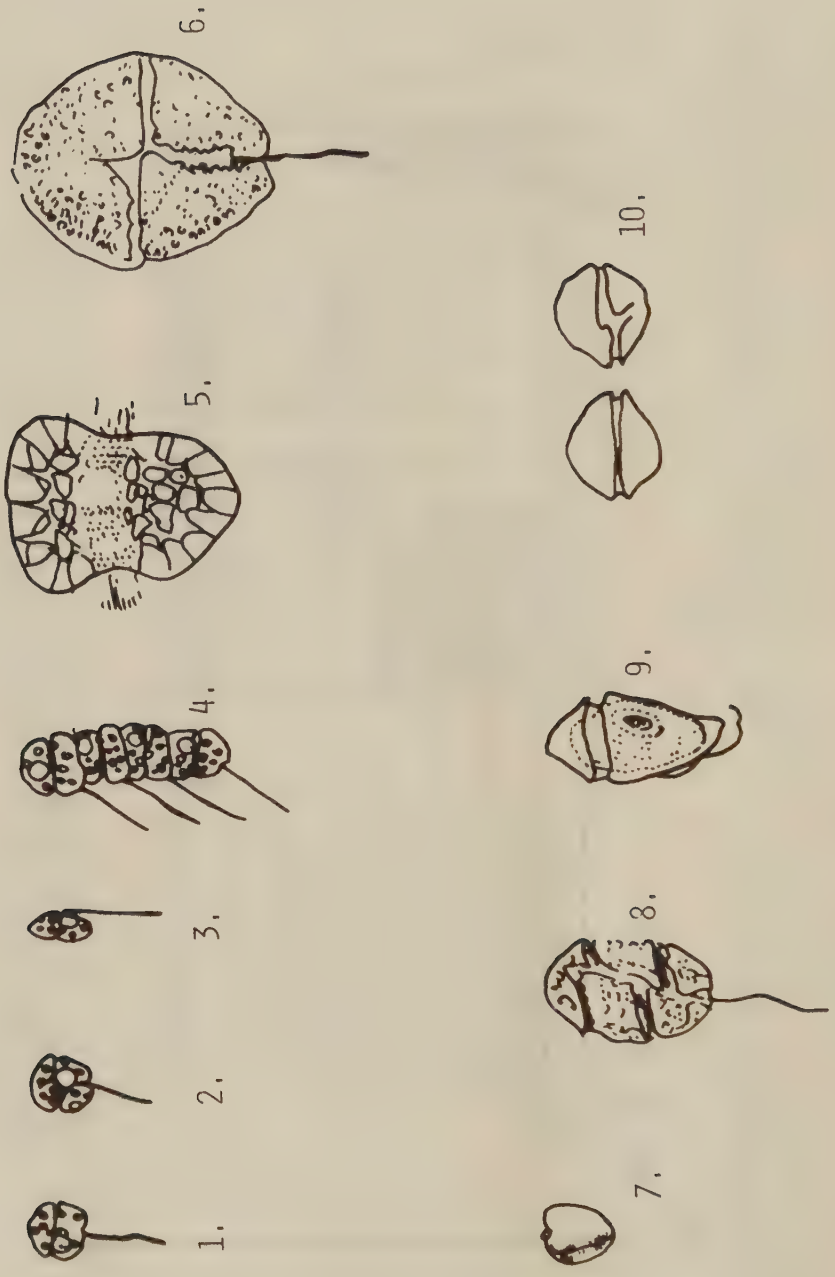


FIG. 15

CHIBA
KAWASAKI
YOKOHAMA
YOKOSUKA
K8
20 m
40 m
60 m
10
5
0 km
A M J J A S O N D J F M
0
1
2
3
4
6

FIG. 10

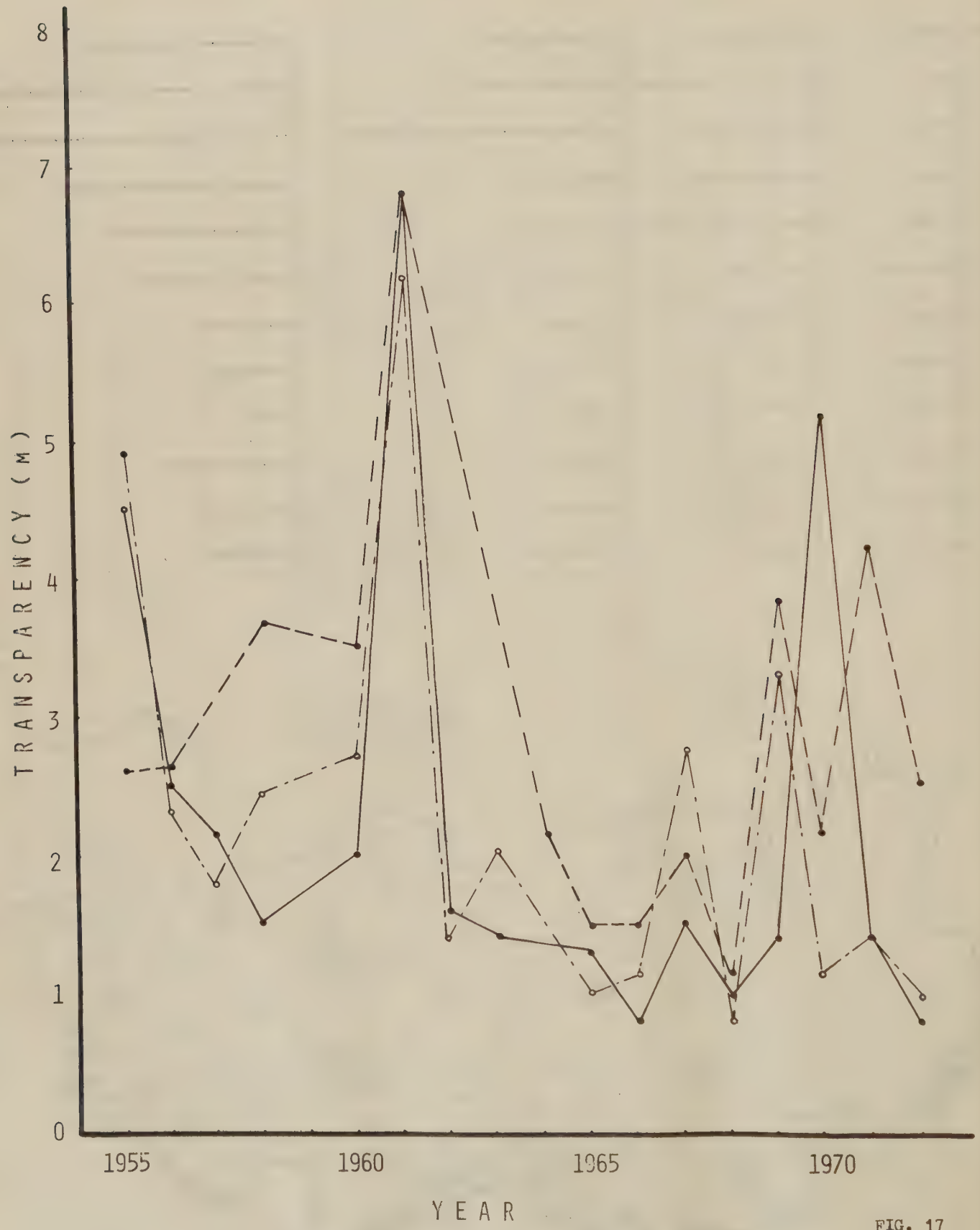


FIG. 17

FIG. 18-1

FIG. 18-2

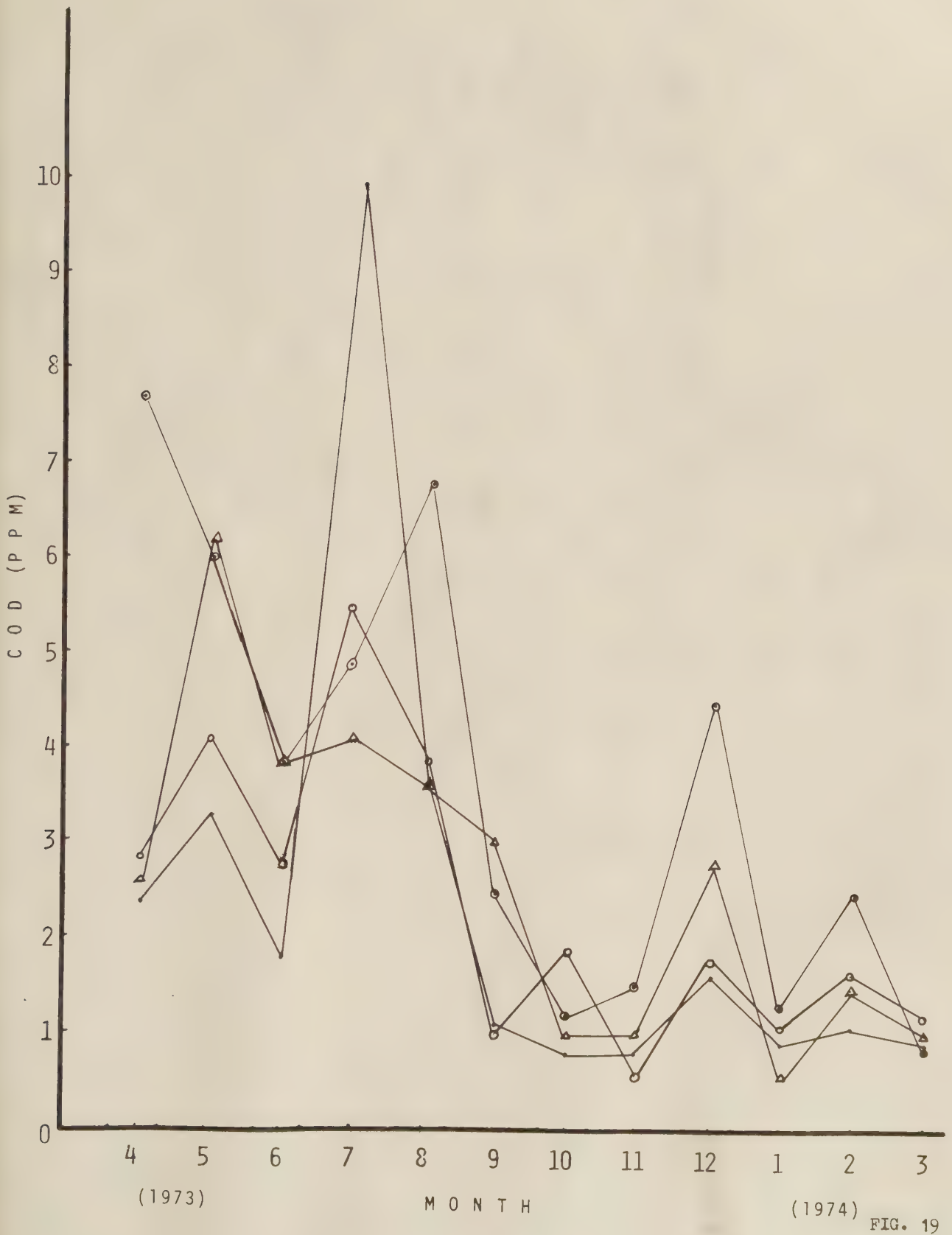


FIG. 19

TOKYO
1.183
1.670
0.933
CHIBA
1.459
1.614
1.005
0.948
0.880
1.219
1.187
1.018
0.797
0.920
1.079
1.008
0.491
1.243
0.584
0.769
0.464
0.905
0.571
KAWASAKI
1.414
0.879
0.851
0.695
0.771
0.785
0.967
0.557
0.755
0.670
0.839
0.581
0.925
YOKOHAMA
0.562
0.915
0.882
0.658
0.634
0.737
0.621
0.875
0.943
0.794
0.607
0.664
0.771
0.365
0.624
0.995
0.561
0.413
0.597
0.609
YOKOSUKA
0.550
0.497
0.486

FIG. 20-1

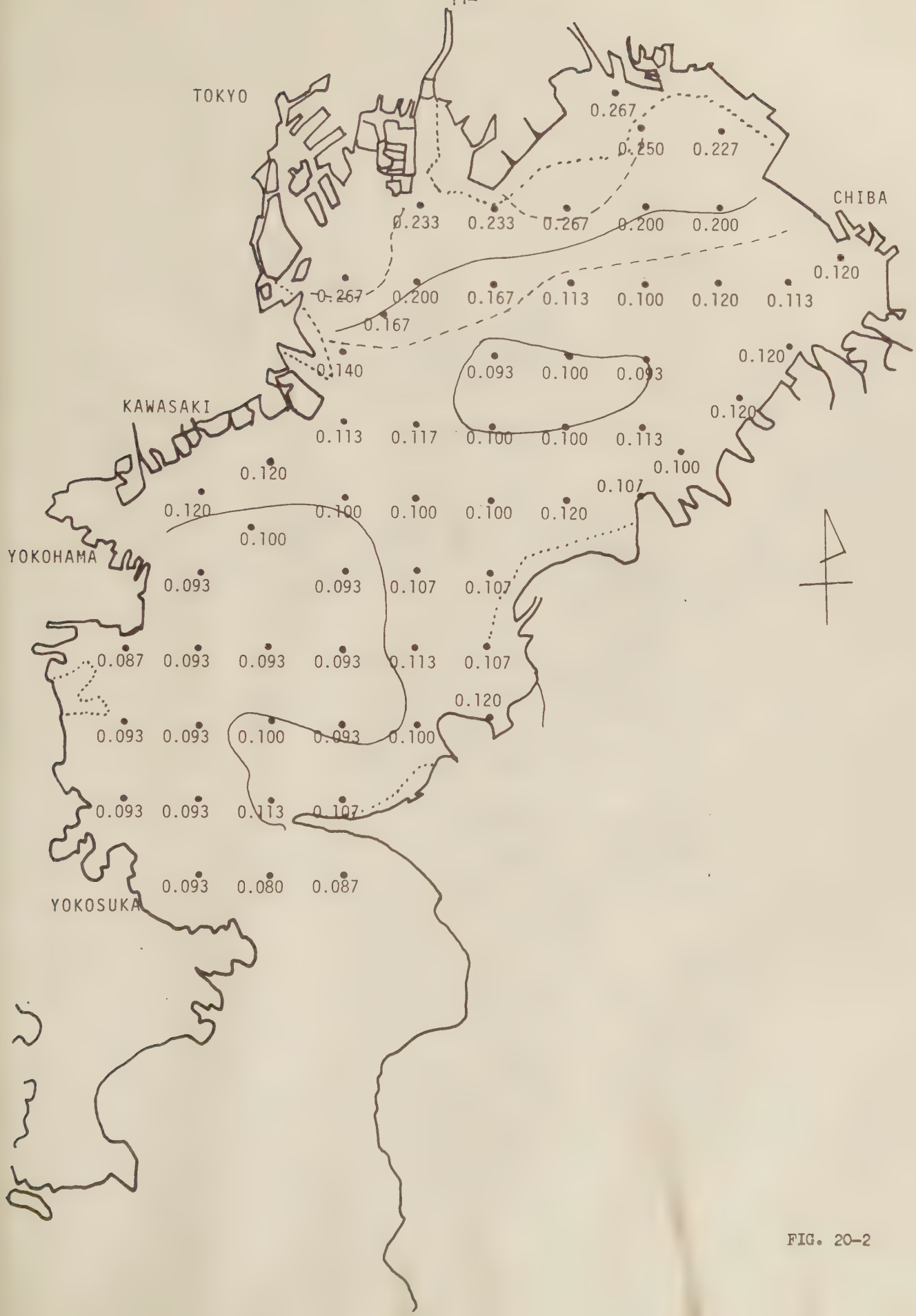

TOKYO
CHIBA
KAWASAKI
YOKOHAMA
YOKOSUKA
0.267
0.250 0.227
0.233 0.233 0.267 0.200 0.200
0.120
0.267 0.200 0.167 0.113 0.100 0.120 0.113
0.167
0.140
0.093 0.100 0.093
0.120
0.120
0.113 0.117 0.100 0.100 0.113
0.100
0.120
0.107
0.120 0.100 0.100 0.100 0.120
0.100
0.093 0.093 0.107 0.107
0.087 0.093 0.093 0.093 0.113 0.107
0.120
0.093 0.093 0.100 0.093 0.100
0.093 0.093 0.113 0.107
0.093 0.080 0.087

FIG. 20-2

TOKYO
CHIBA
KAWASAKI
YOKOHAMA
YOKOSUKA
69.7
61.2
69.7
46.4
59.1
36.3
36.8
30.2
31.9
32.0
30.3
29.9
28.2
37.3
38.6
28.1
24.9
26.7
33.9
39.7
33.6
32.5
28.7
24.4
28.1
39.4
43.7
35.0
24.4
27.7
31.9
30.4
32.4
29.7
51.4
41.2
40.6
51.1
67.0
40.6
53.5
52.2
67.8
64.5
71.9

FIG. 21-1

TOKYO
CHIBA
KAWASAKI
YOKOHAMA
YOKOSUKA
7.3
6.4
2.8
8.1
8.8
4.6
10.4
9.4
11.9
11.1
11.8
14.9
13.3
13.3
10.7
9.5
13.0
9.8
8.7
15.2
12.6
12.2
12.0
10.7
11.5
15.7
12.7
12.2
9.8
14.4
9.2
11.0
13.4
16.6
13.0
15.9
11.7
11.7
11.9
11.4
7.9
12.1
15.4
11.4
9.5
5.0
12.8
9.8
9.2
9.7
6.9
11.0
12.1
6.2
6.4
2.1
4.8
9.6
6.4

FIG. 21-2

TOKYO
CHIBA
KAWASAKI
YOKOHAMA
YOKOSUKA
0.25
0.08 0.25
0.65 0.43 0.26 0.40 0.36
0.79
0.41 0.84 0.25 0.32 0.37 0.35 0.20
0.11
0.43
0.20 0.99 0.31 0.44
0.42
0.67 0.76 0.30 0.25 0.12
0.19
0.17 0.43
0.91 0.91 0.21 0.84 0.28
1.47
0.97 0.08 0.84 0.74
0.24 0.32 0.21 0.21
0.49
0.18
0.48 0.39 0.33 0.32 0.41 0.10
0.02 0.36 0.34 0.21
0.30 0.06 0.12

FIG. 21-3

FIG. 22(a)

FIG. 22(b)

FIG. 22(c)

FIG. 22(d)

FIG. 22(e)

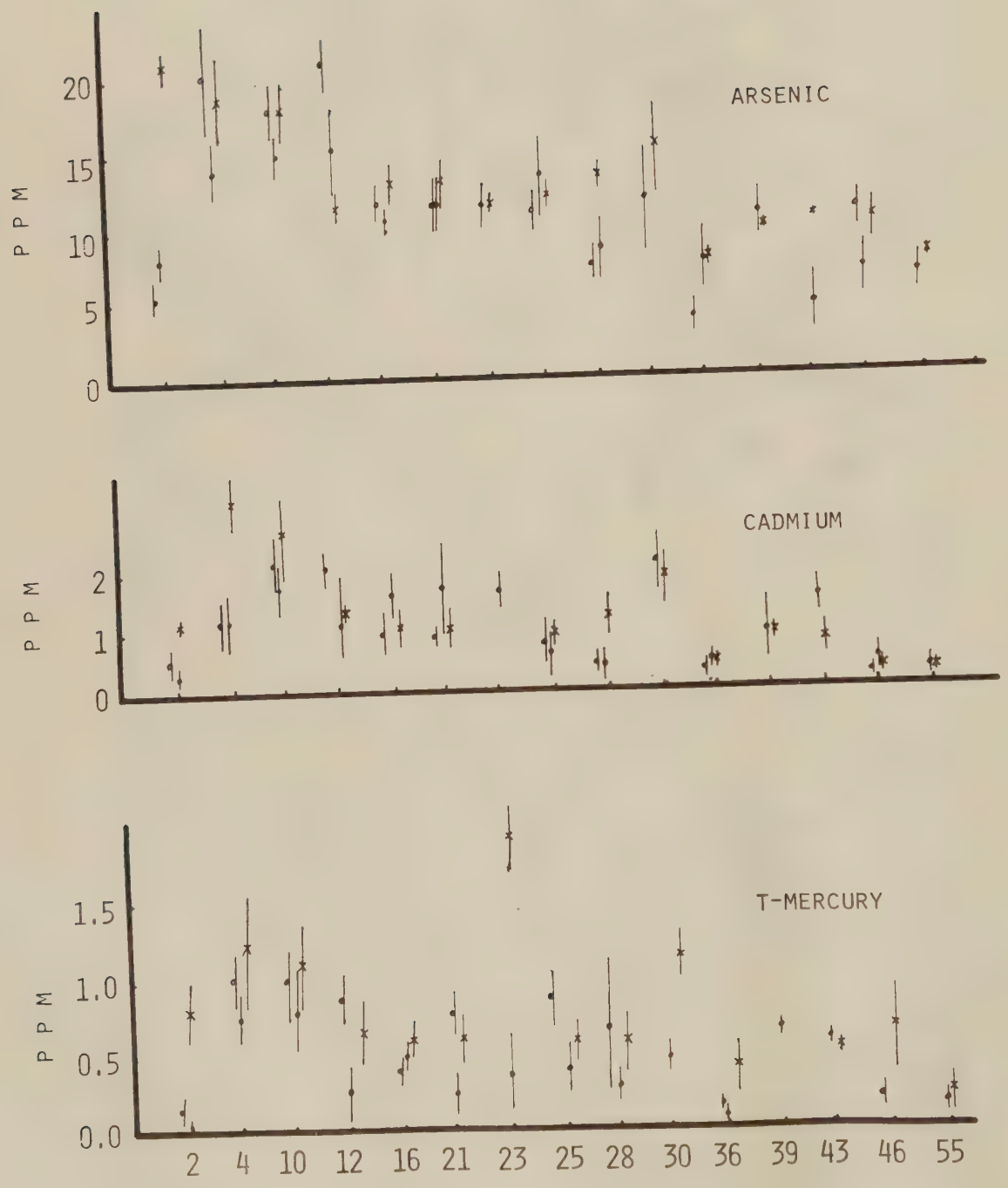

ARSENIC
PPM
20
15
10
5
0
CADMIUM
PPM
2
1
0
T-MERCURY
PPM
1.5
1.0
0.5
0.0
2 4 10 12 16 21 23 25 28 30 36 39 43 46 55

FIG. 23(a)

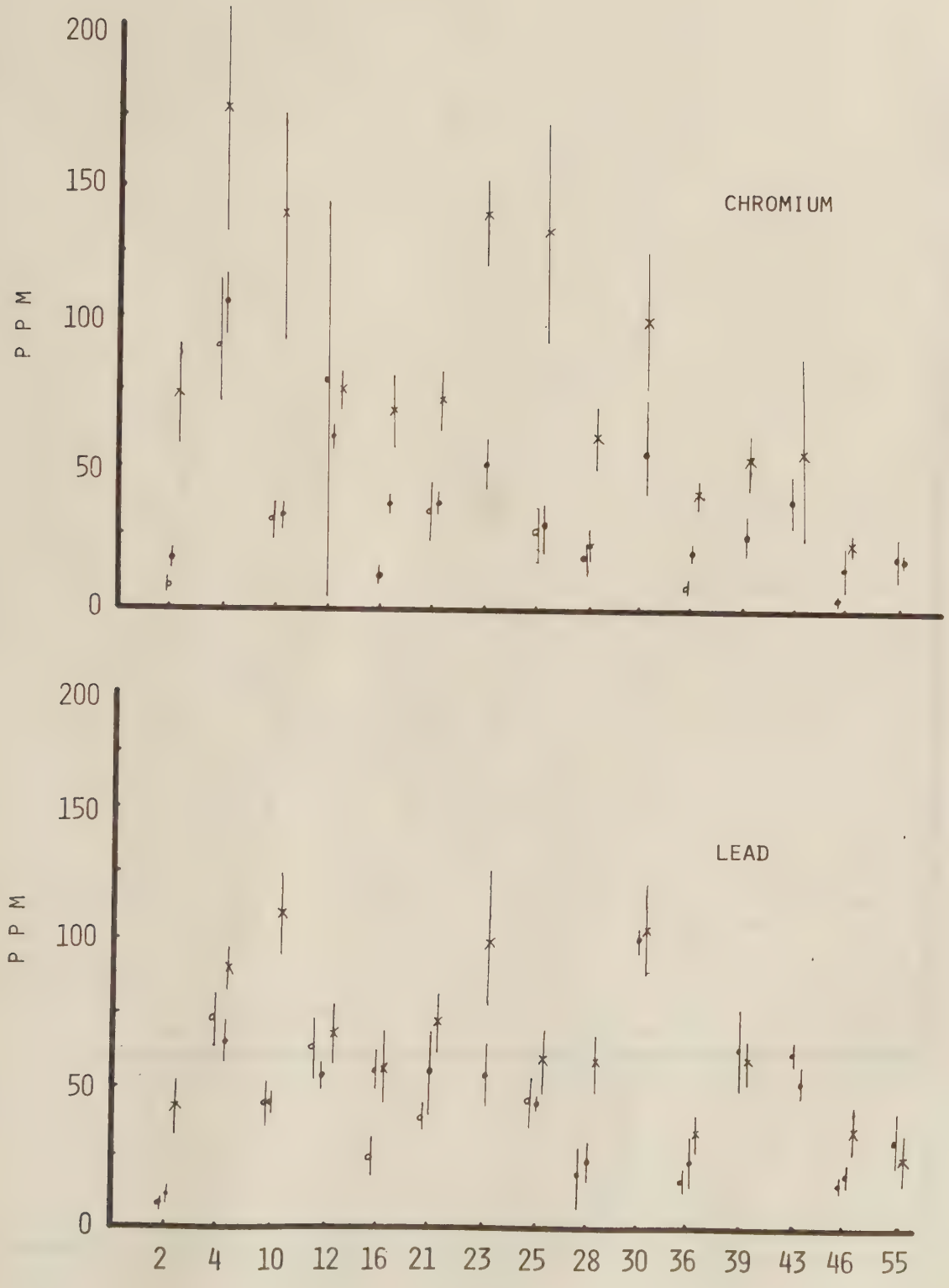

200
150
100
50
0
PPM
CHROMIUM
200
150
100
50
0
PPM
LEAD
2
4
10
12
16
21
23
25
28
30
36
39
43
46
55

FIG. 23(b)

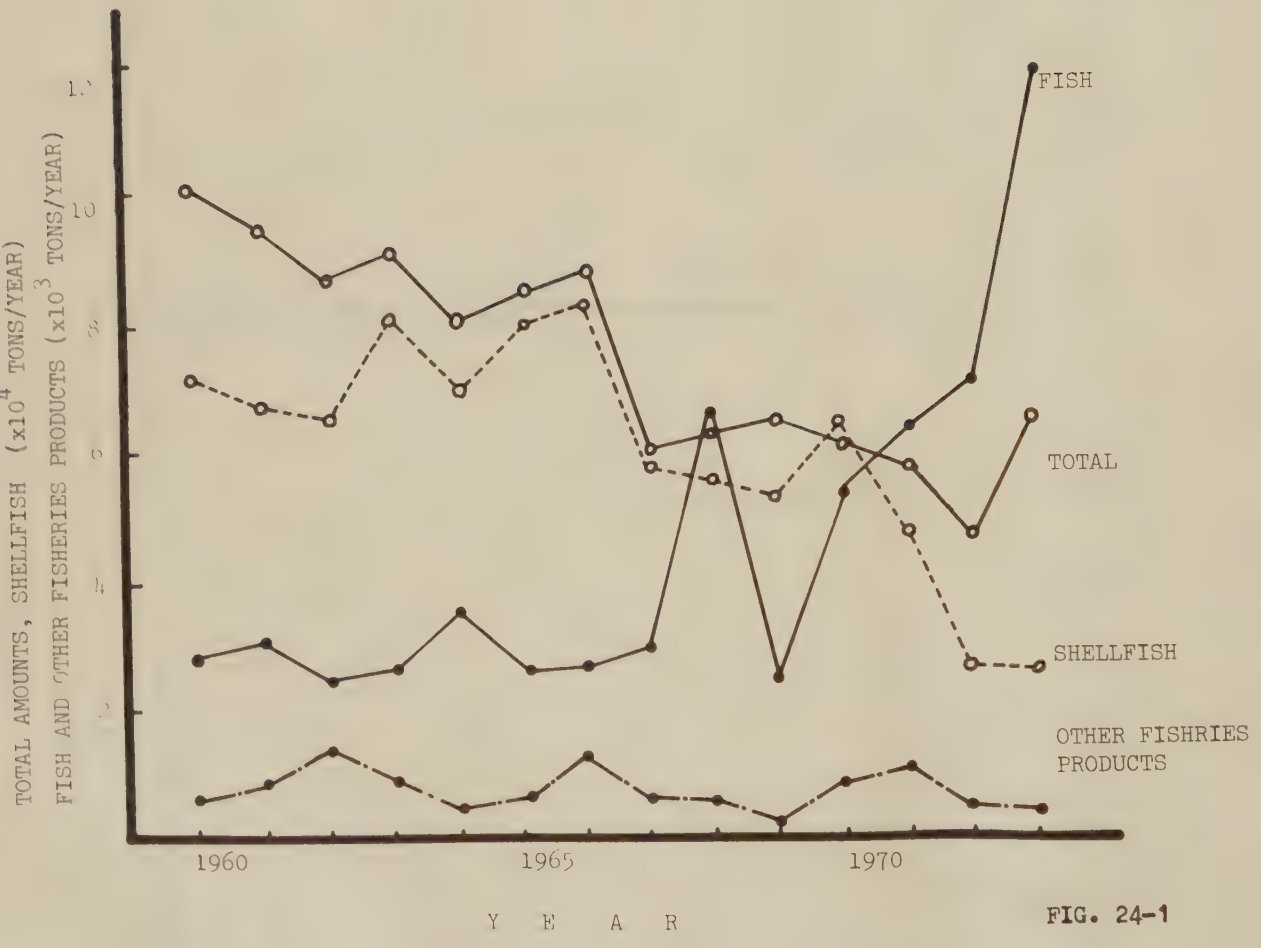

FISH
TOTAL
SHELLFISH
OTHER FISHRIES PRODUCTS
1960
1965
1970
Y E A R
TOTAL AMOUNTS, SHELLFISH (x10^4 TONS/YEAR)
FISH AND OTHER FISHERIES PRODUCTS (x10^3 TONS/YEAR)

FIG. 24-1

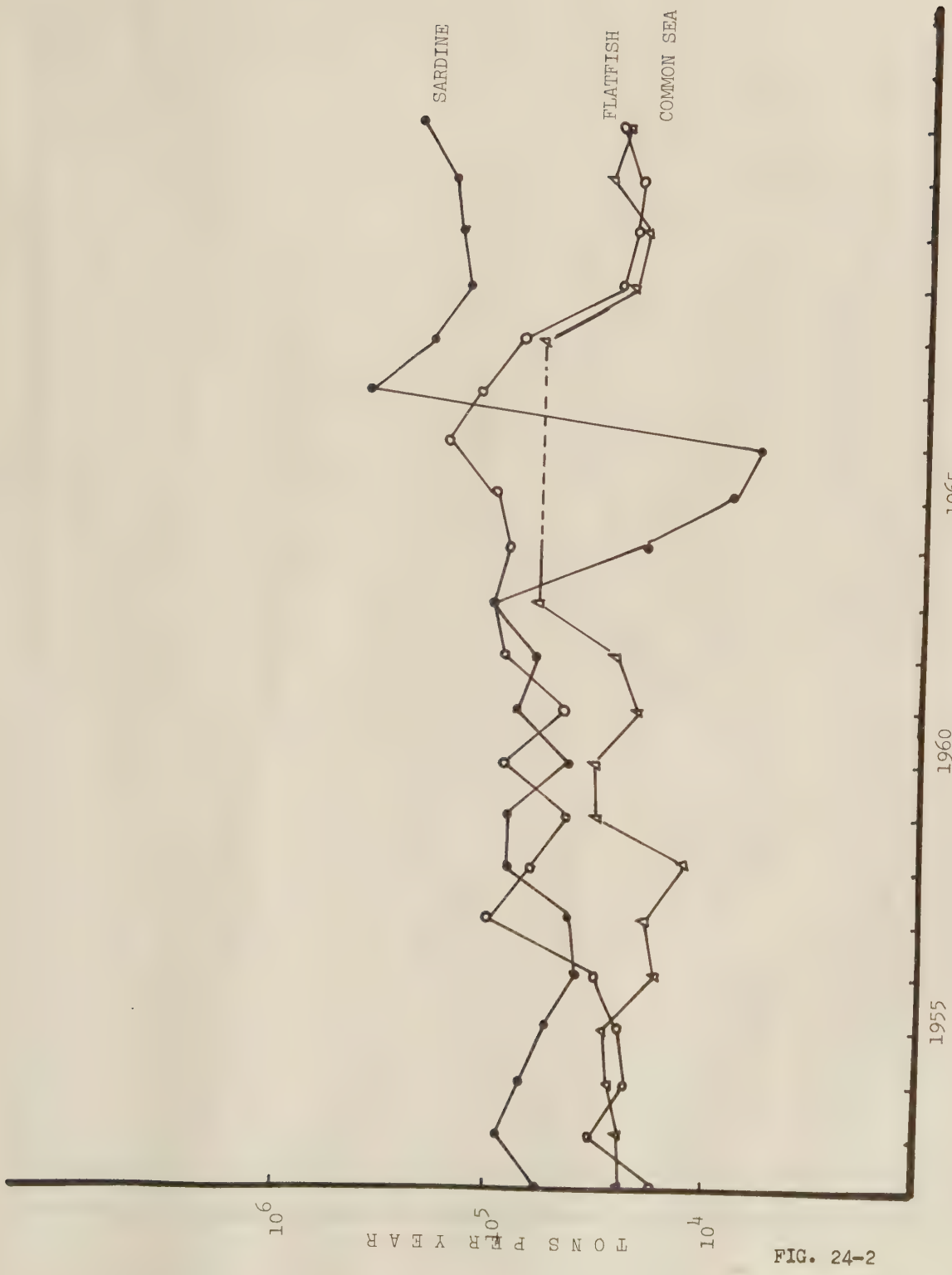

SARDINE
FLATFISH
COMMON SEA BASS
1955
1960
1965
1970
10^6
10^5
10^4
TONS PER YEAR

FIG. 24-2

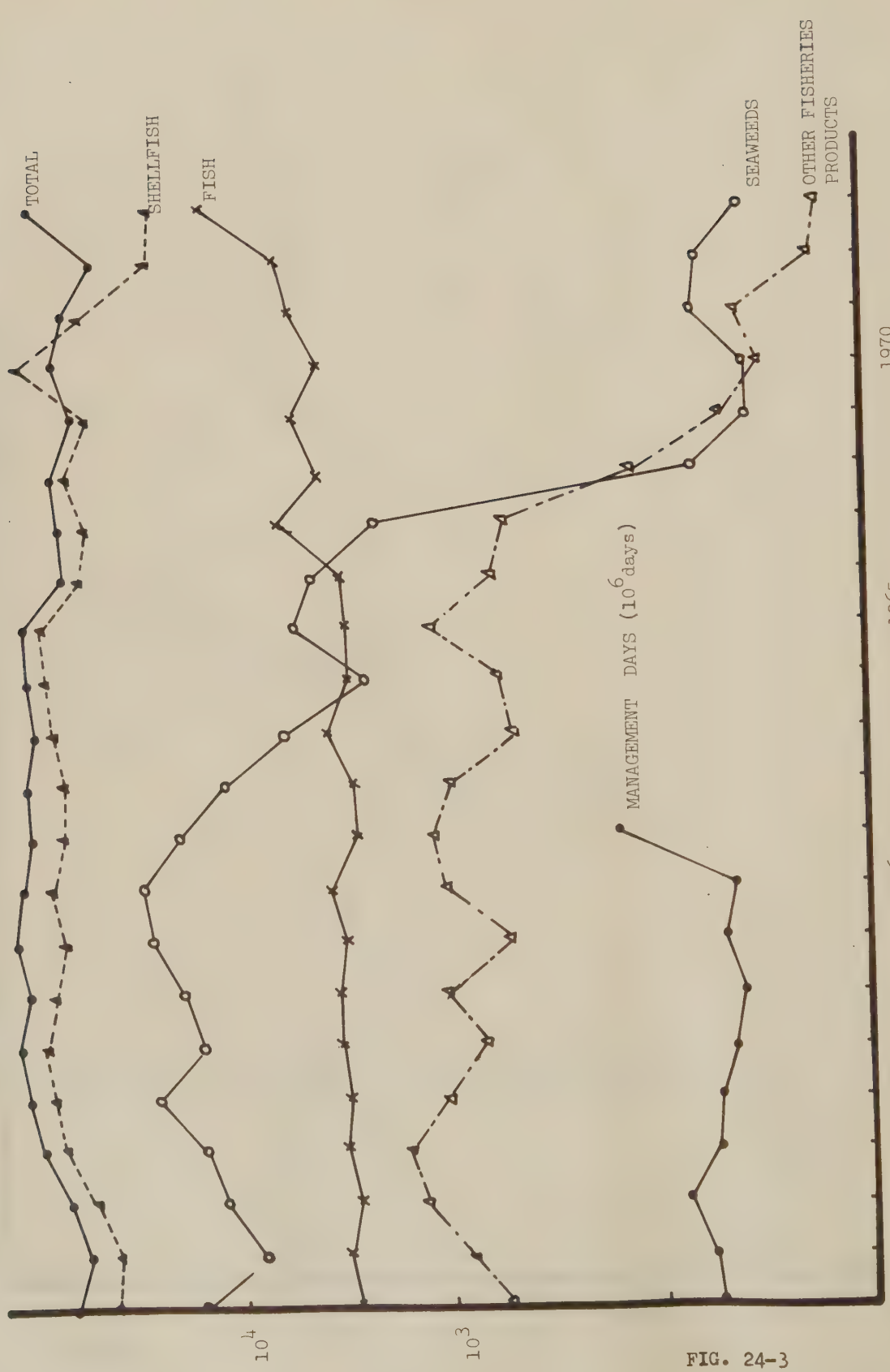

TOTAL
SHELLFISH
FISH
SEAWEEDS
OTHER FISHERIES PRODUCTS
MANAGEMENT DAYS (10^6 days)
10^4
10^3
1955
1960
1965
1970

FIG. 24-3

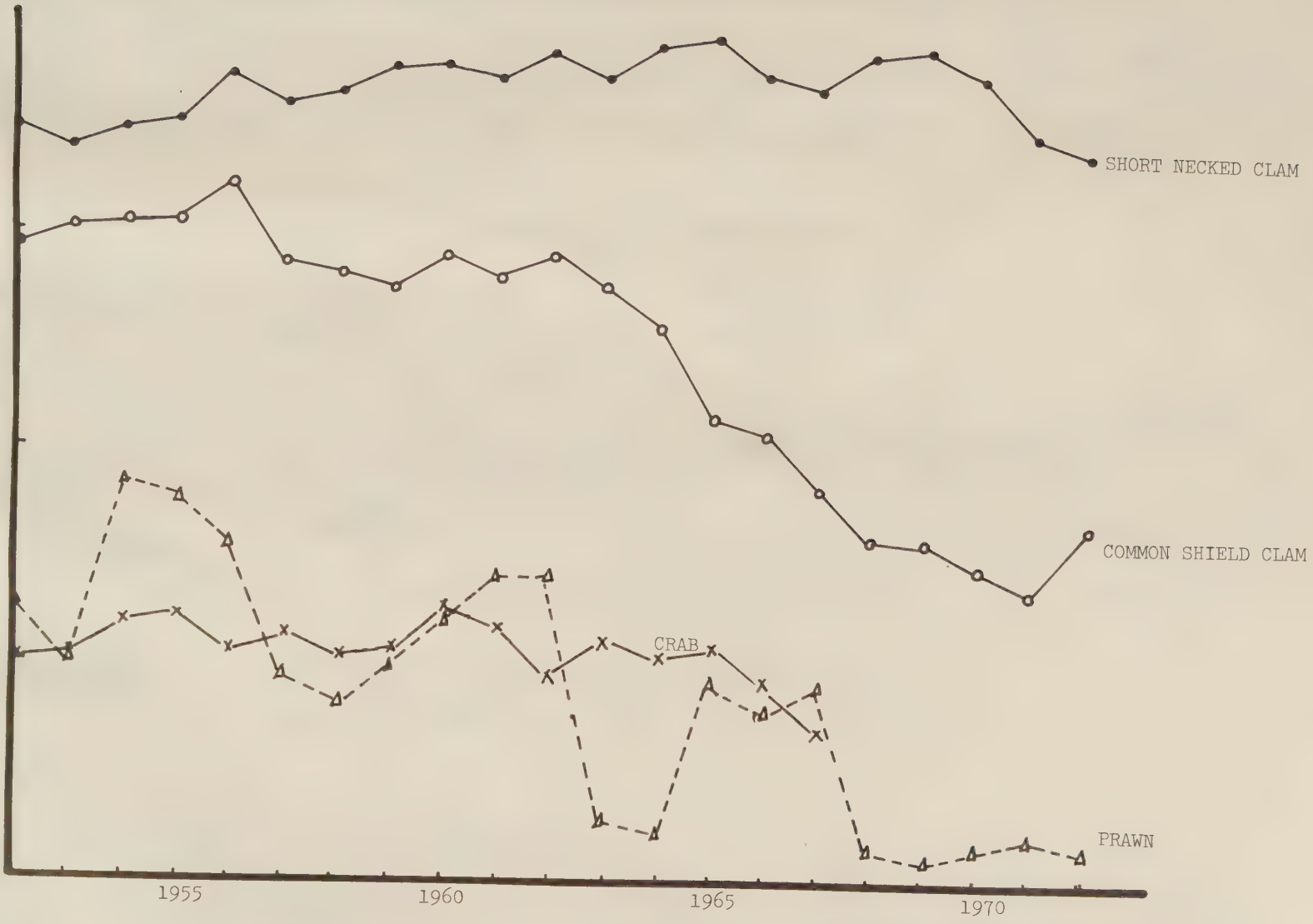

SHORT NECKED CLAM
COMMON SHIELD CLAM
CRAB
PRAWN
10^4
10^3
10^2
1955
1960
1965
1970

FIG. 24-4

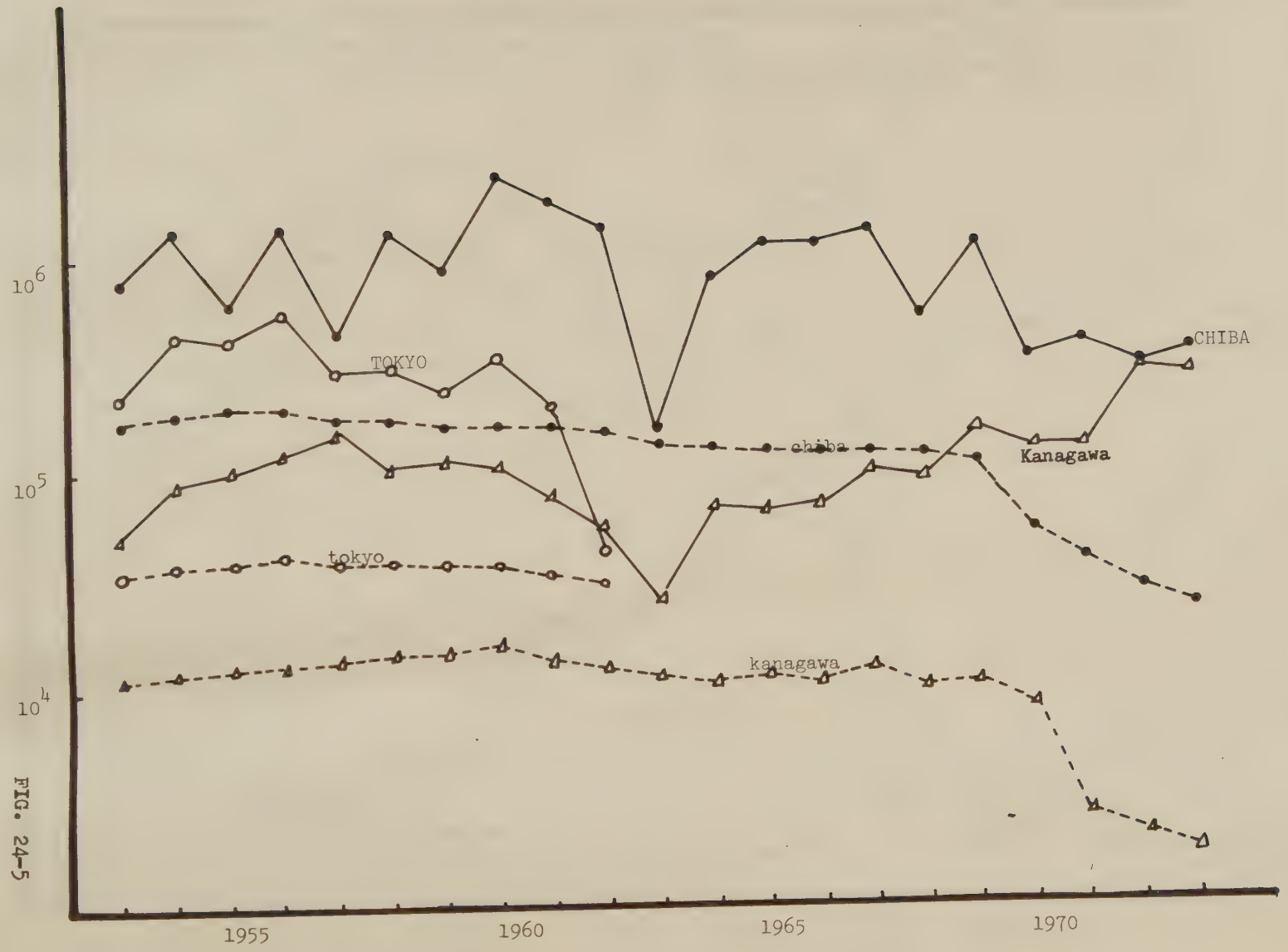

10^6
10^5
10^4
TOKYO
CHIBA
chiba
Kanagawa
tokyo
kanagawa
1955
1960
1965
1970

FIG. 24-5

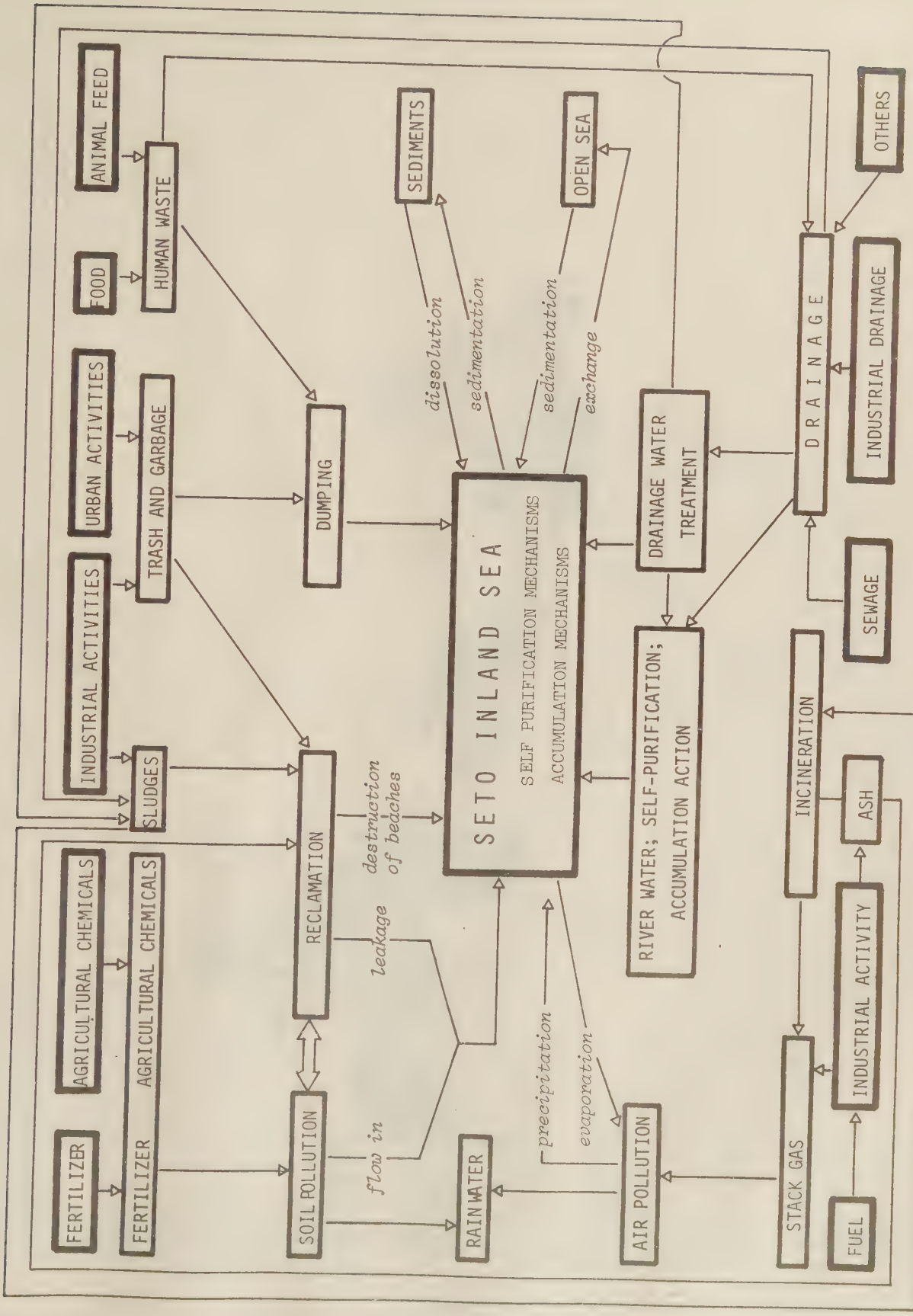

ANIMAL FEED
FOOD
HUMAN WASTE
SEDIMENTS
OPEN SEA
OTHERS
URBAN ACTIVITIES
TRASH AND GARBAGE
DUMPING
dissolution
sedimentation
sedimentation
exchange
DRAINAGE
INDUSTRIAL DRAINAGE
INDUSTRIAL ACTIVITIES
SLUDGES
SETO INLAND SEA
SELF PURIFICATION MECHANISMS
ACCUMULATION MECHANISMS
DRAINAGE WATER TREATMENT
SEWAGE
INCINERATION
ASH
AGRICULTURAL CHEMICALS
AGRICULTURAL CHEMICALS
FERTILIZER
FERTILIZER
RECLAMATION
destruction of beaches
leakage
RIVER WATER; SELF-PURIFICATION; ACCUMULATION ACTION
SOIL POLLUTION
flow in
precipitation
evaporation
RAIN WATER
AIR POLLUTION
STACK GAS
INDUSTRIAL ACTIVITY
FUEL

FIG. 25

SEA OF JAPAN
KOBE
OKAYAMA
FUKUYAMA
HIROSHIMA
TOKUYAMA
TAKAMATSU
SHIMONOSEKI
UBE
WAKAYAMA
IYO-MISHIMA
TOKUSHIMA
NIIHAMA
MATSUYAMA
KII
CHANNEL
UWAJIMA
BEPPU
BUNGO
CHANNEL
0 50 100 km
1/1,200,000

FIG. 26

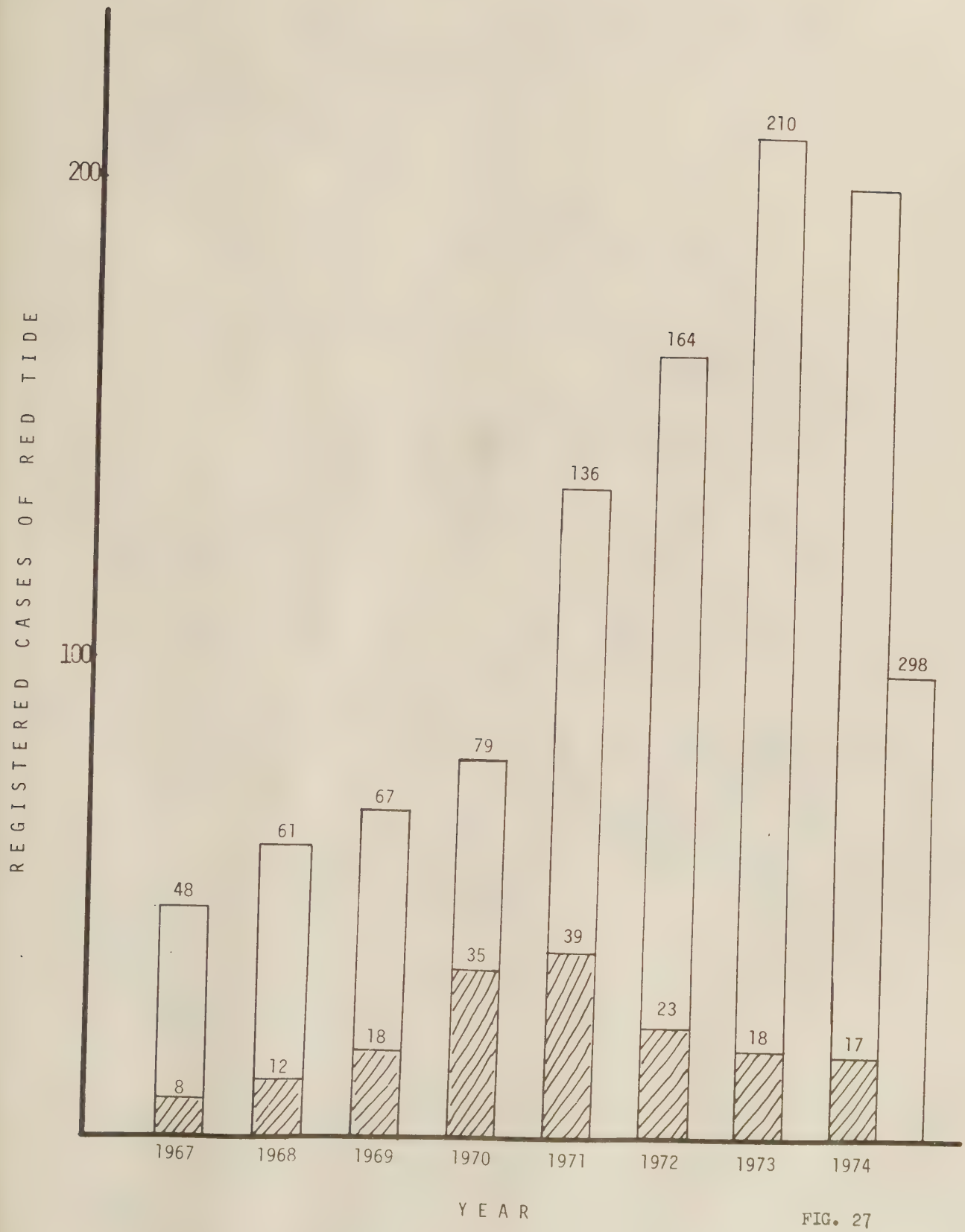

200
100
REGISTERED CASES OF RED TIDE
48
8
61
12
67
18
79
35
136
39
164
23
210
18
298
17
1967
1968
1969
1970
1971
1972
1973
1974
YEAR

FIG. 27

FIG. 28

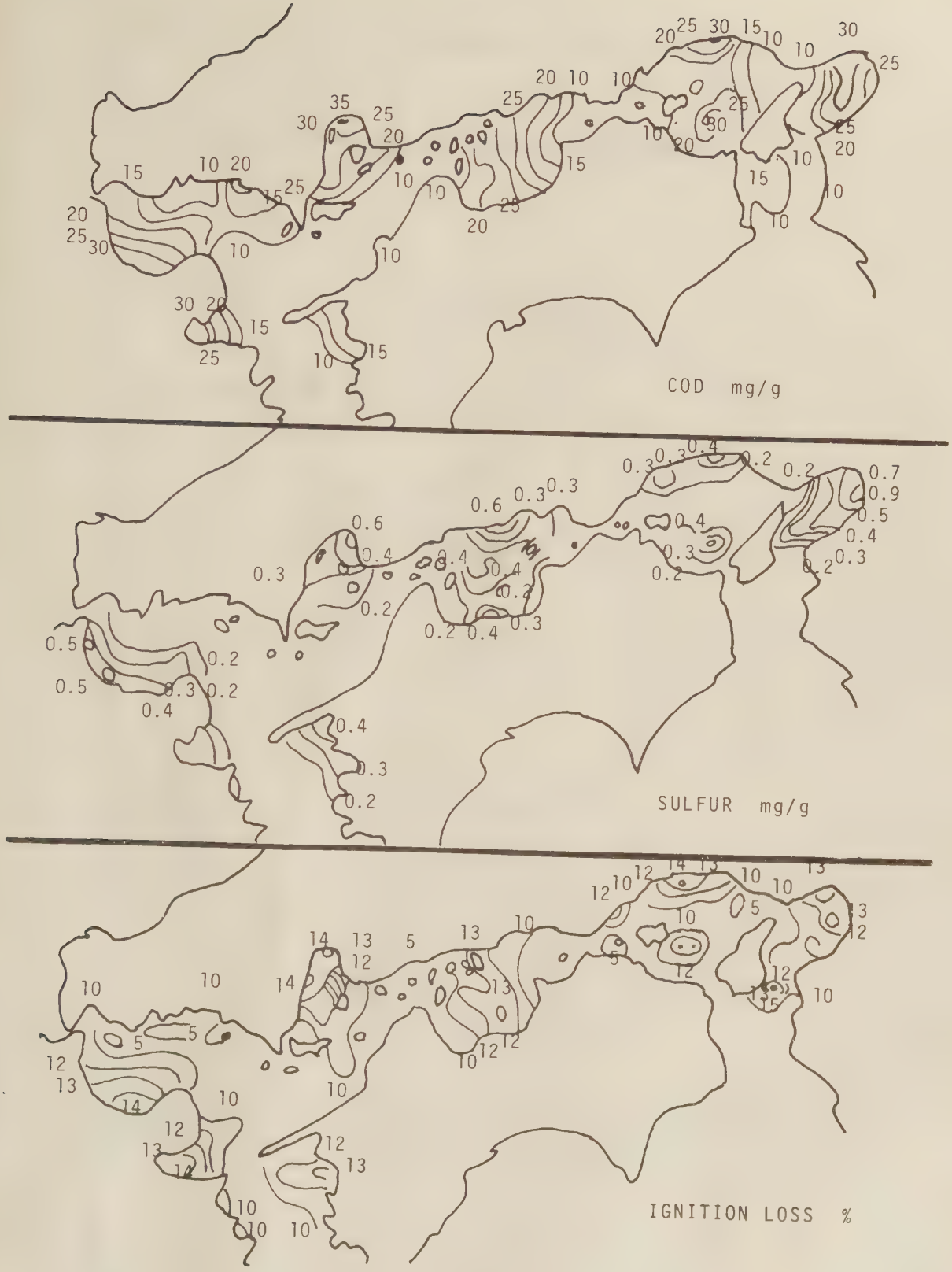


FIG. 29

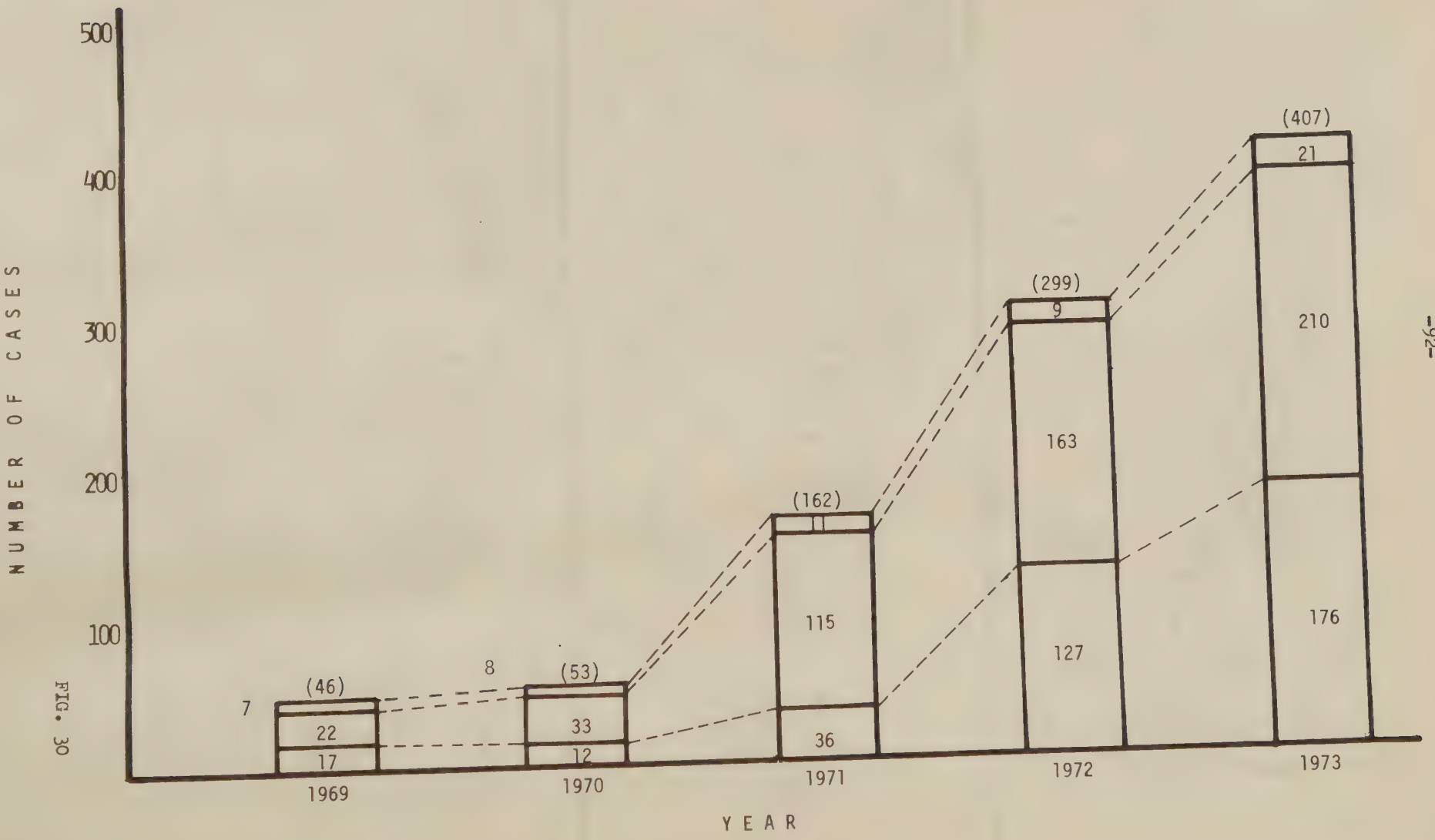

500
400
300
200
100
NUMBER OF CASES
(46)
7
22
17
1969
8
(53)
33
12
1970
(162)
115
36
1971
(299)
9
163
127
1972
(407)
21
210
176
1973
YEAR

FIG. 30

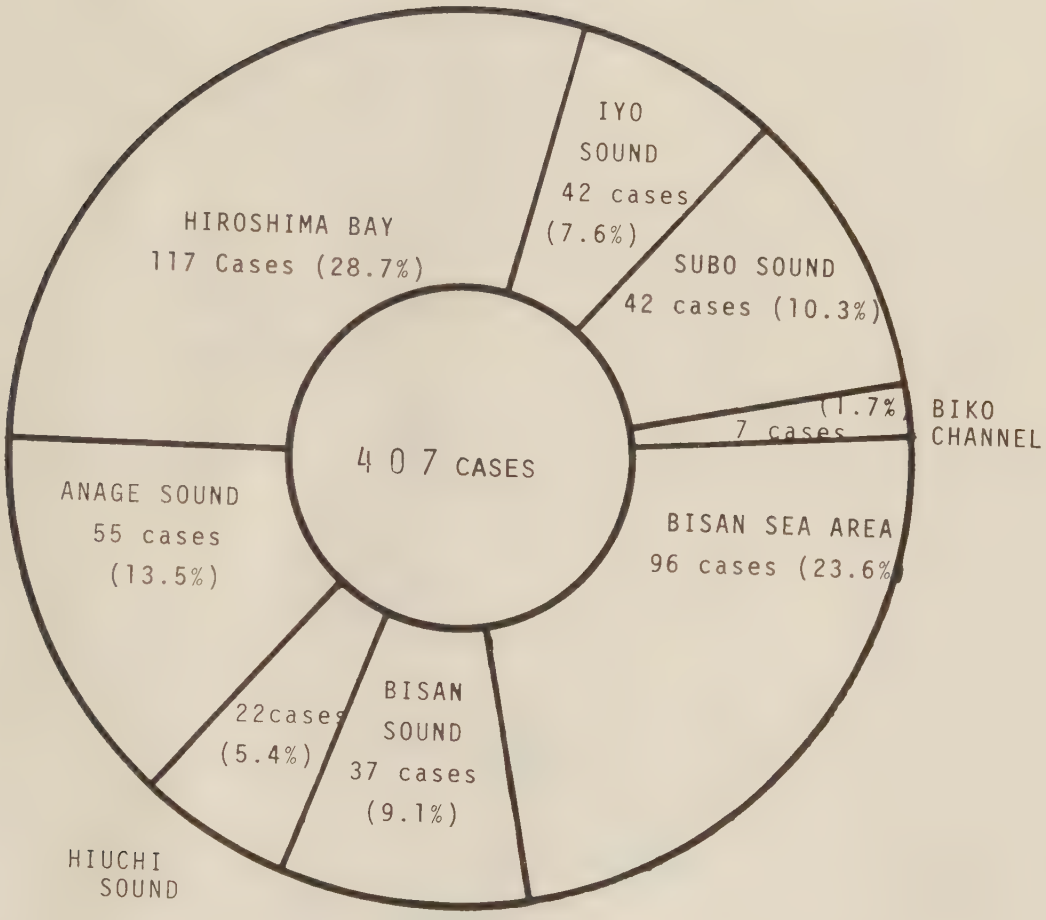


FIG. 31. CASES OF OIL POLLUTION IN DIFFERENT AREAS OF THE SETO INLAND SEA. From "The Present Situation of Maritime Safety, 1974", by the Maritime Safety Agency.

FIG. 32. CASES OF OIL POLLUTION ACCORDING TO VESSEL DISTINCTION. From "The Present Situation of Maritime Safety, 1974", by the Maritime Safety Agency.

FIG. 33. EEL GRASS ("amamo," *Zostera*) ZONES PRIOR TO 1965 IN DIFFERENT REGIONS OF THE SETO INLAND SEA, AND THEIR REDUCTION RATES UP TO 1965. BLACK - PROPORTION OF REMAINING AREA; WHITE - PROPORTION OF VANISHED AREA. NUMBERS SHOW THE AREA IN HECTARES PRIOR TO 1965. Data from the Southwest Regional Fisheries Research Laboratory.

FIG. 34. EEL GRASS ("amamo," *Zostera*) ZONES PRIOR TO 1965 IN DIFFERENT REGIONS OF THE SETO INLAND SEA, AND THEIR REDUCTION RATES BETWEEN THE YEARS 1965 TO 1971. SYMBOLIC REPRESENTATION AND NUMERALS ARE THE SAME AS GIVEN IN FIG. 33. Data from the Southwest Regional Fisheries Research Laboratory.

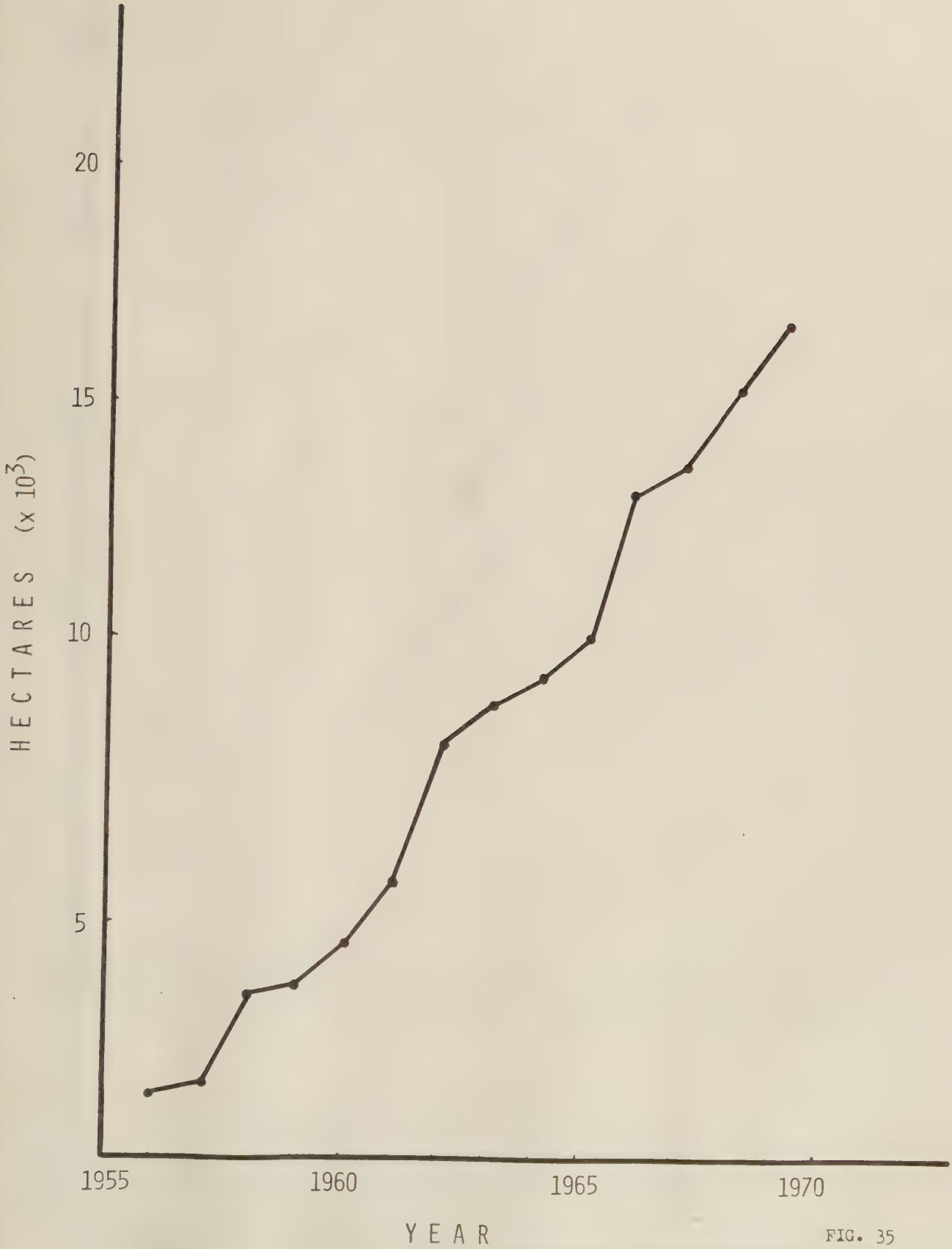


FIG. 35

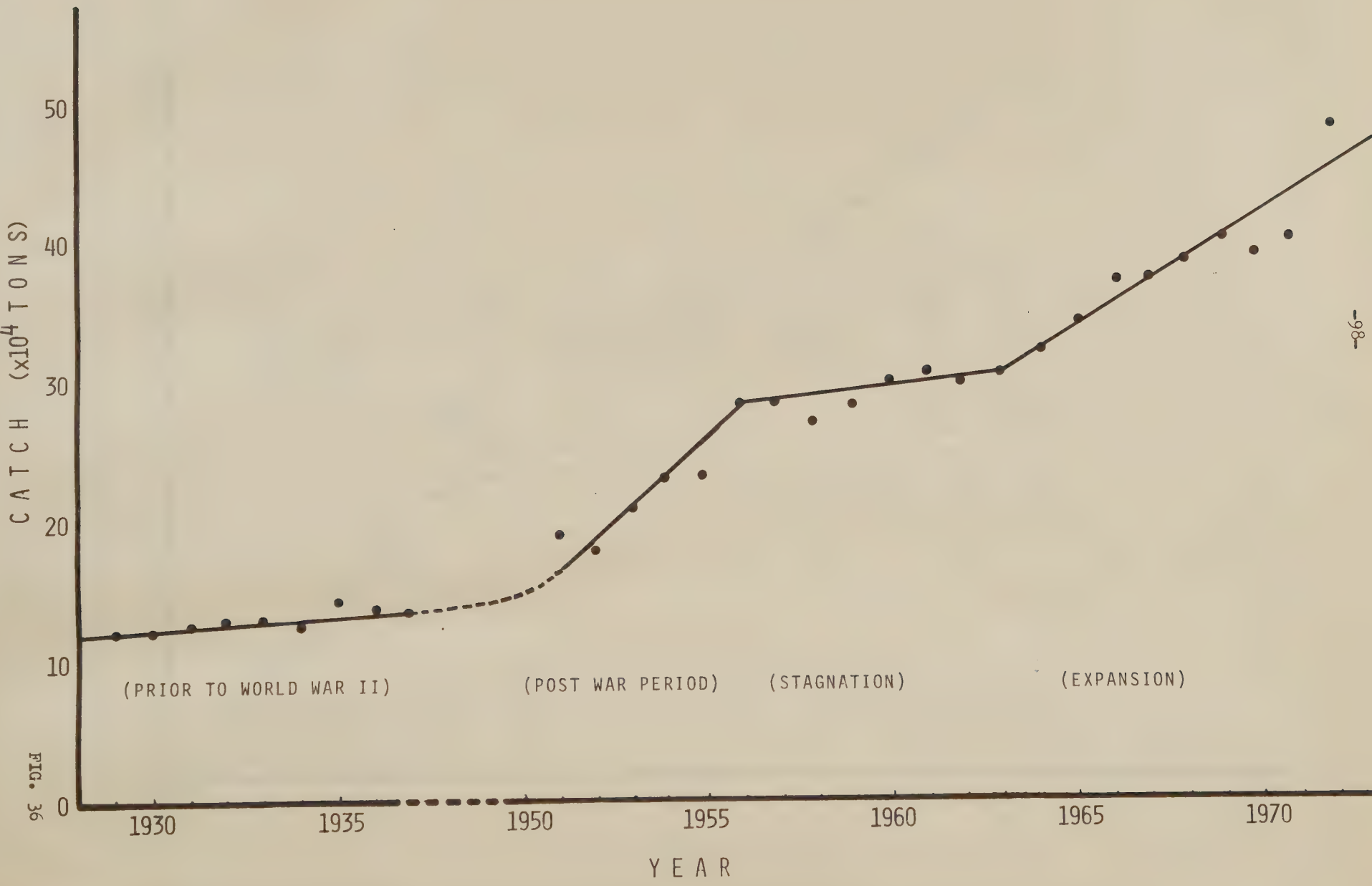

CATCH (x10⁴ TONS)
50
40
30
20
10
0
1930
1935
1950
1955
1960
1965
1970
YEAR
(PRIOR TO WORLD WAR II)
(POST WAR PERIOD)
(STAGNATION)
(EXPANSION)

FIG. 36

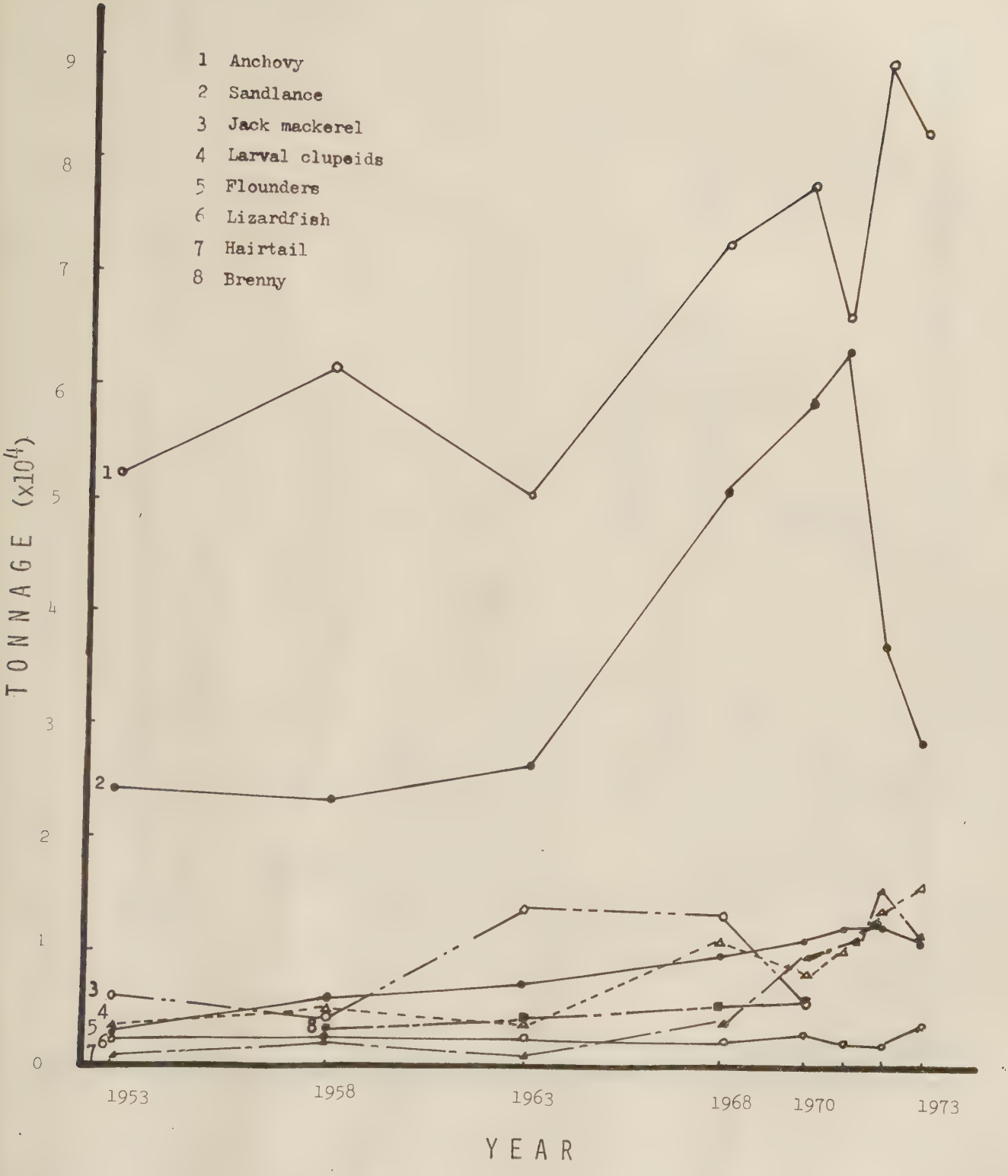


FIG. 37. CHANGES IN THE AMOUNT OF MAJOR FISHERIES PRODUCTS IN THE SETO INLAND SEA. Data from the Fishery and Aquaculture Yearbook of the Ministry of Agriculture and Forestry for 1953, and the Fisheries Statistic Table in the Seto Inland Sea from the Chugoku-Shikoku Agricultural Administration Bureau for the years 1958 to 1973.

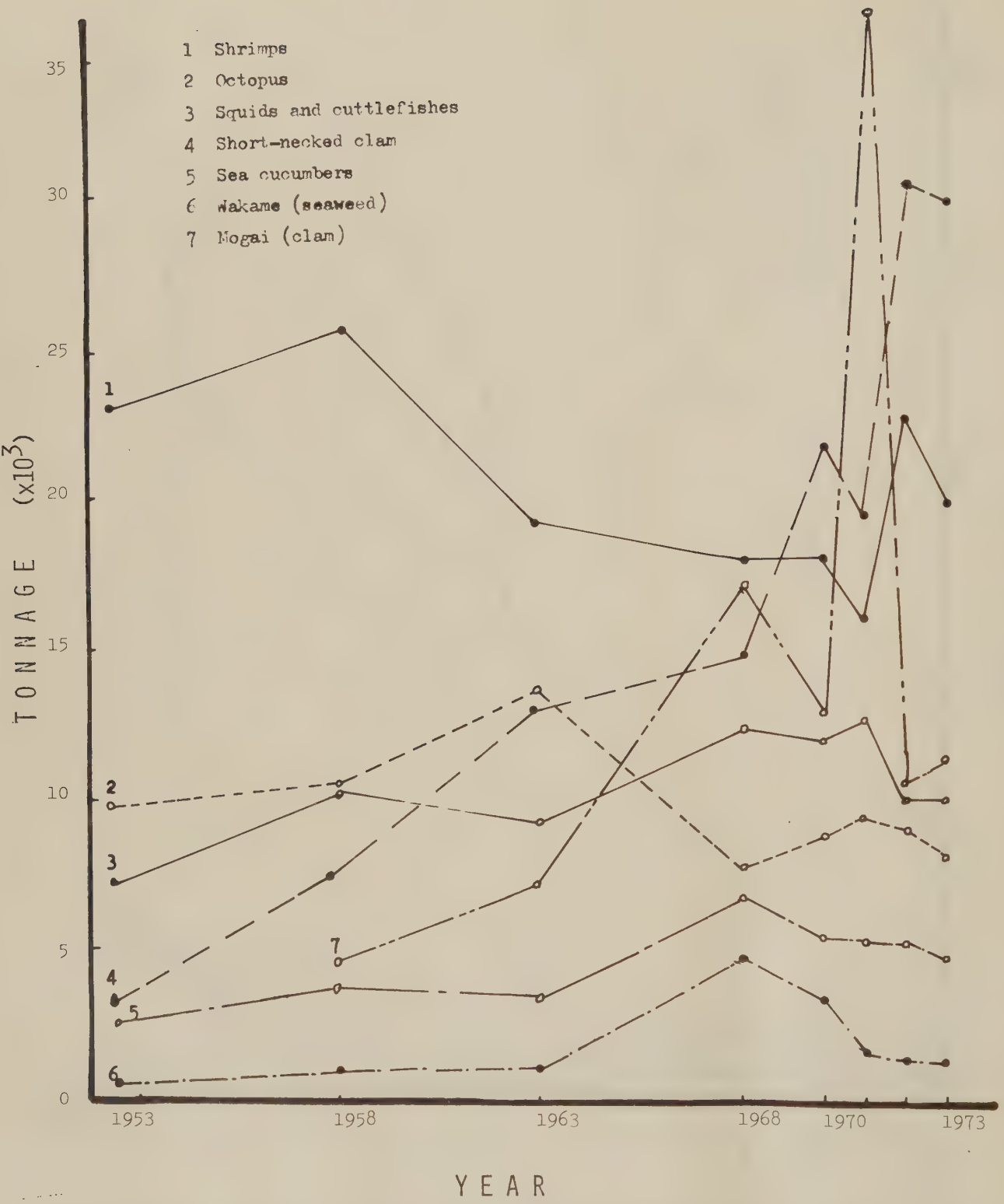


FIG. 38. CHANGES IN THE AMOUNT OF MAJOR MARINE PRODUCTS (MARINE ANIMALS, SHELLFISH, AND SEAWEEDS) IN THE SETO INLAND SEA. Data from the Fishery and Aquaculture Yearbook of the Ministry of Agriculture and Forestry for 1953, and the Fisheries Statistic Table in the Seto Inland Sea from the Chugoku-Shikoku Agricultural Administration Bureau for the years 1958 to 1973.

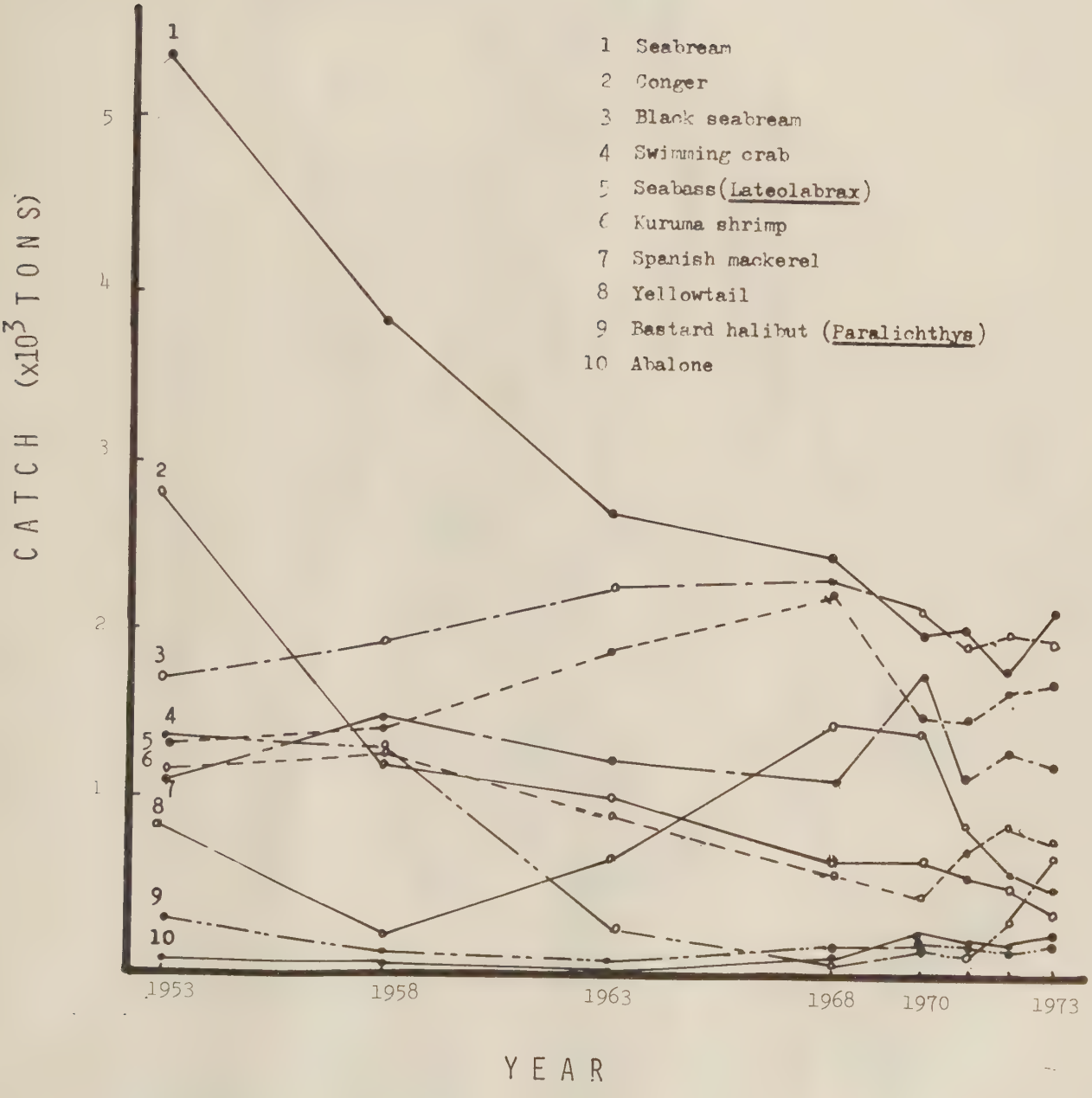


FIG. 39. CHANGES IN THE CATCHES OF DIFFERENT FISHES. Data from the Fishery and Aquaculture Yearbook of the Ministry of Agriculture and Forestry for 1953, and the Fisheries Statistic Table in the Seto Inland Sea from the Chugoku-Shikoku Agricultural Administration Bureau for the years 1958 to 1973.

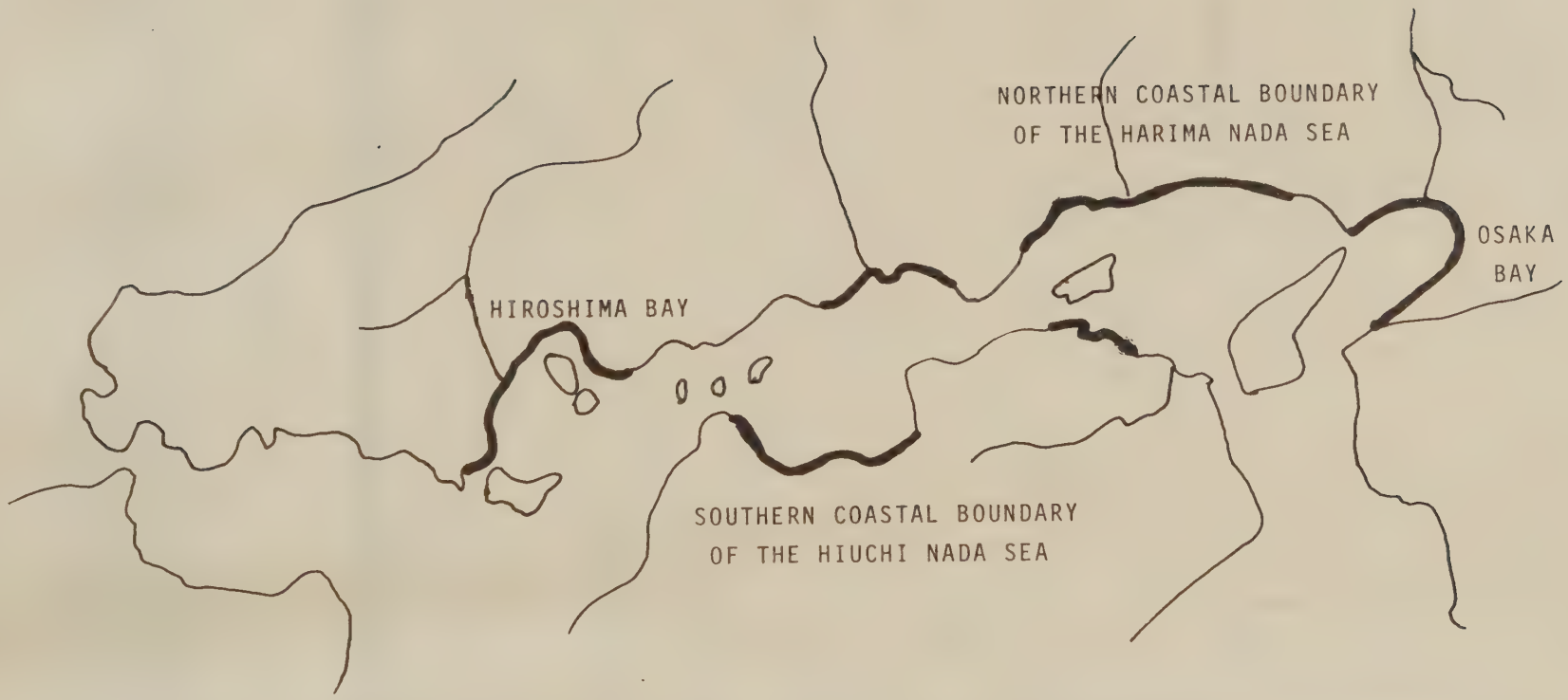
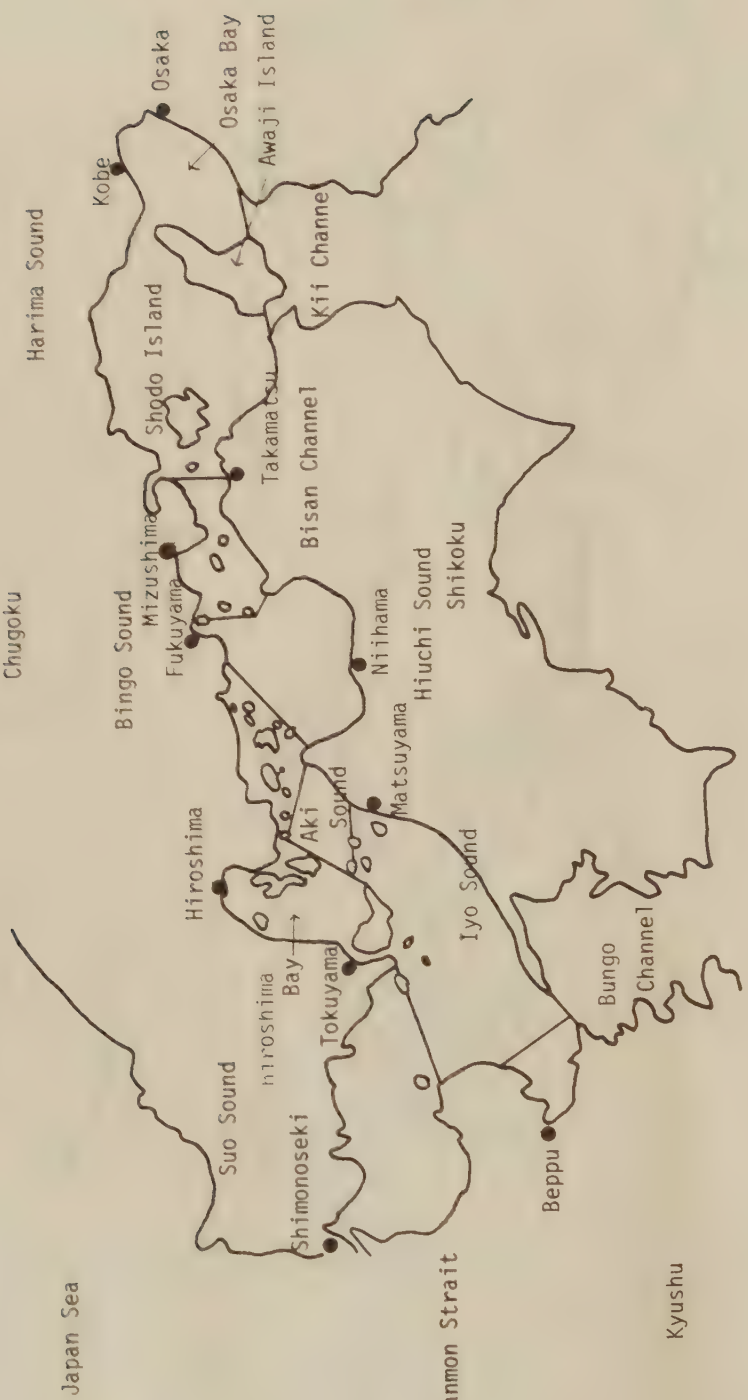


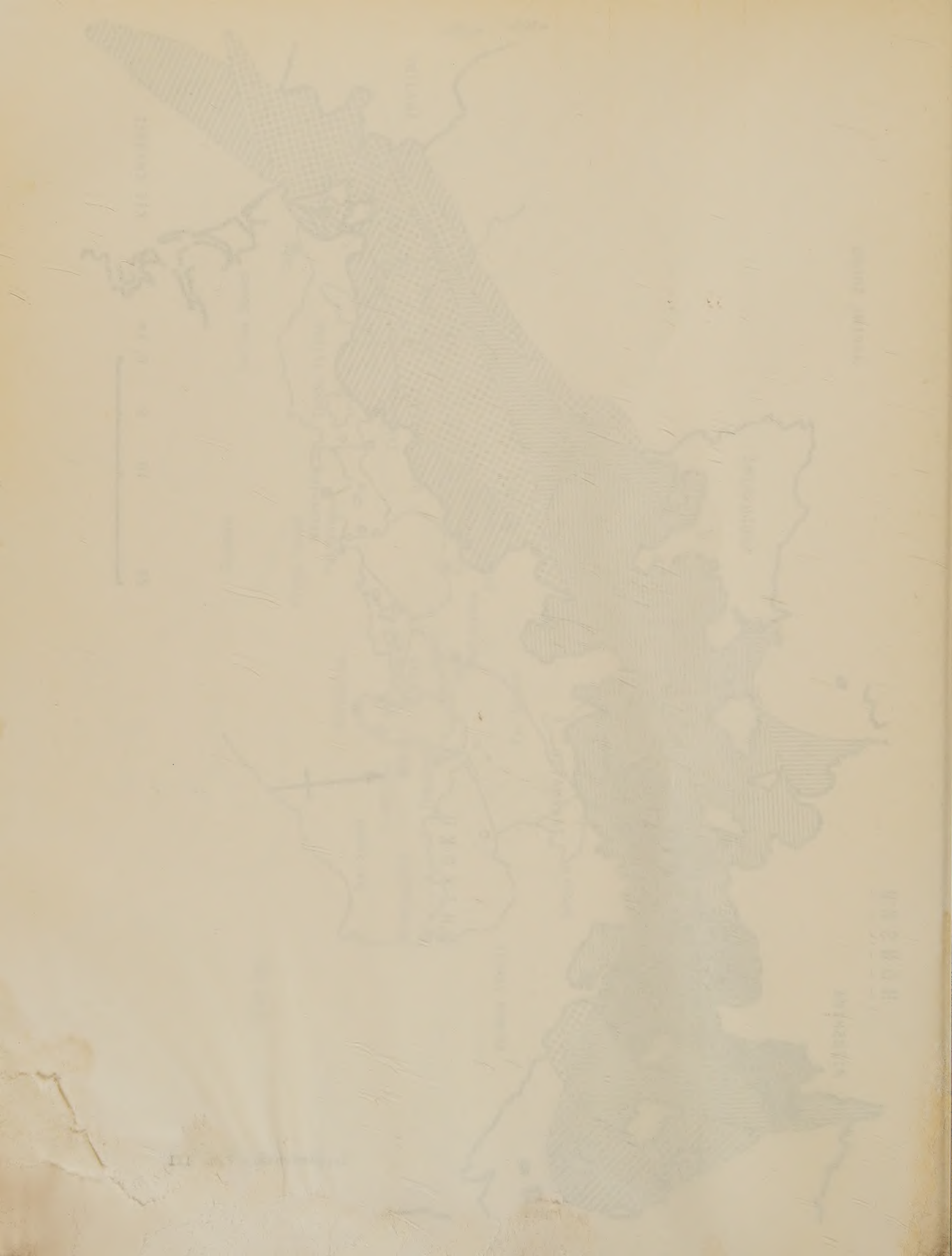
FIG. 40. AREAS OF THE SETO INLAND SEA WHICH HAVE BEEN DESIGNATED AS THOSE WHERE RECLAMATION WORK SHOULD BE AVOIDED. Data from the Environmental Agency.

Supplementary FIG. 1



Supplementary
FIG. II

Supplementary FIG. III



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